DECEMBER 1960

Journal

VOL. 52 • NO. 12

AMERICAN WATER WORKS ASSOCIATION

In this issue:

GROUND WATER RECHARGE
Sniegocki, Broadhurst, Welsch

WELL STIMULATION
Koenig

STATUS OF FLUORIDATION, 1959
Task Group Report

IDENTIFICATION GUIDE TO ANIMALS
Ingram, Bartsch

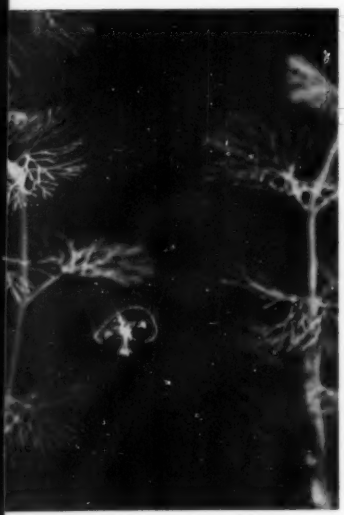
EFFECTS OF FISH POISONS
Cohen, Kamphake, Lemke, Henderson, Woodward

SUGGESTED DETERMINATION METHODS
Lee, Stumm, Goldman, Dietz

COLIFORM ORGANISMS AND POLLUTION
Kabler, Clark

CONFERENCE AND SECTION PROGRAMS
1960 Meetings

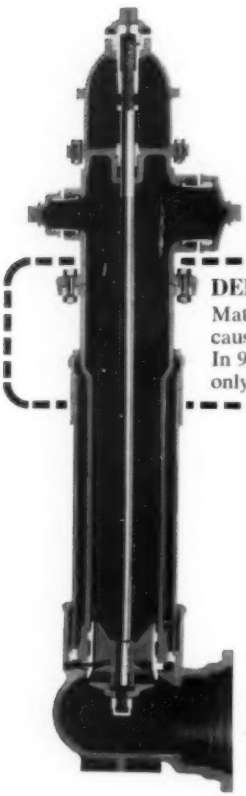
JOURNAL AWWA SUBJECTS AND AUTHORS
1960 Indexes



Merry Craspedacusta decorating underwater Yule tree to furnish fitting Seasons Greetings!

1961 AWWA CONFERENCE
Detroit, June 4-9

ONLY MATHEWS HAS ALL THE DESIRABLE FEATURES



What do you look for in a hydrant? Dependability? . . . replaceable barrel? . . . conventional packing? . . . "O" ring seal? . . . stop nut to prevent stem from buckling? We could double this list and still not cover all the features we build into Mathews Hydrants *by design*. Mathews has them all.

DEPENDABILITY

Mathews Hydrants are always ready for service, because their design is fundamentally sound and simple. In 90 years we have never changed the basic design—only refined it, by detail.

AND ALL THESE OTHER FEATURES, TOO:
All working parts contained in replaceable barrel • Head can be faced in any direction • Replaceable head • Any nozzles you specify • Nozzle levels raised or lowered without excavating • Leakproof because stuffing box is cast integral with nozzle section • Operating thread only part requiring lubrication • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Available with bell, mechanical joint or flange pipe connections

Conform to latest AWWA specifications

R. D. WOOD COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers also of Mathews Flange Barrel Hydrants, R. D. Wood Hydrants, R. D. Wood Gate Valves, and "Sand-Spun" Pipe (centrifugally cast in sand molds)

Journal

AMERICAN WATER WORKS ASSOCIATION

2 PARK AVE., NEW YORK 16, N.Y. • Phone: MUrray Hill 4-6686

December 1960

Vol. 52 No. 12

Contents

Ground Water Recharge and Conservation

Effects of Viscosity and Temperature.....Richard T. Sniegocki 1487

Practices on the High Plains of Texas.....William L. Broadhurst 1491

Conservation in Nassau County.....W. Fred Welsch 1494

Effects of Stimulation on Well Operating Costs and Its Performance on Old and New Wells.....Louis Koenig 1499

Status of Fluoridation in the United States and Canada, 1959....Task Group Report 1513

Operators' Identification Guide to Animals Associated With Potable Water Supplies
William M. Ingram & Alfred F. Bartsch 1521

Effect of Fish Poisons on Water Supplies—Part 1: Removal of Toxic Materials
Jesse M. Cohen, Lawrence J. Kamphake, Armond E. Lemke, Croswell Henderson & Richard L. Woodward 1551

Binding the Year's Journals..... 1566

Determination of Ferrous Iron in the Presence of Ferric Iron With Bathophenanthroline.....G. Fred Lee & Werner Stumm 1567

Suggested Amperometric Titration Method for Determining Dissolved Oxygen
Eugene Goldman & Bernard Dietz 1575

Coliform Group and Fecal Coliform Organisms as Indicators of Pollution in Drinking Water.....Paul W. Kabler & Harold F. Clark 1577

Notes and Comment: Filter Sand Grain Growth Due to Manganese Dioxide
D. L. Erickson 1580

80th Annual Conference—Bal Harbour..... 1581

Papers Scheduled at 1960 Section Meetings..... 1593

AWWA Publications List..... 1607

Index for Volume 52, 1960

Subject Index..... 1615

Author Index..... 1634

Departments

Officers and Directors..... *2 P&R*

Coming Meetings..... *6 P&R*

Percolation and Runoff..... *31 P&R*

Employment Information..... *48 P&R*

Condensation..... *58 P&R*

Index to Advertisers' Products... *86 P&R*

Raymond J. Faust, *Secretary*
Lawrence Farber, *Managing Editor*
Arne E. Gubrud, *Associate Editor*

Eric F. Johnson, *Director of Publications*
Robert A. Nye, *Production Manager*
Milton Horowitz, *Assistant Editor*

Journal AWWA is published monthly at Prince & Lemon Sts., Lancaster, Pa., by the Am. Water Works Assn., Inc., 2 Park Ave., New York 16, N.Y. Second-class postage paid at Lancaster, Pa. Authorized Aug. 6, 1918. $8.00 of members' dues are applied as a subscription to the Journal; additional single copies—85 cents. Indexed annually in December; and regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm edition (for Journal subscribers only) by University Microfilms, Ann Arbor, Mich.

© 1960, by the American Water Works Association, Inc. Made in U.S.A.

AWWA Officers and Directors

President	C. F. WERTZ	*Treasurer*	WILLIAM J. ORCHARD
Vice-President	JOHN W. CRAMER	*Secretary*	RAYMOND J. FAUST
Ch. W.W. Practice Com.	LOUIS R. HOWSON	*Asst. Secretary*	ERIC F. JOHNSON
Ch. W.W. Admin. Com.	WENDELL R. LADUE	*Asst. Secretary*	JAMES B. RAMSEY
Ch. Publication Com.	E. SHAW COLE	*Asst. Secretary*	DAVID B. PRESTON
Past-President	LAUREN W. GRAYSON		

Officers of the Sections

Section	*Director*	*Chairman*	*Vice-Chairman*	*Secretary-Treasurer*
Alabama-Miss.	J. L. Haley	C. M. Mathews	C. C. Williams	Ernest Bryan
Arizona	L. O. Gardner	R. E. Polenske	S. I. Roth	A. D. Cox
California	H. C. Medbery	M. K. Socha	H. J. Ongerth	F. F. Watters
Canadian	C. S. Anderson	J. D. Kline	G. E. Maxwell	A. E. Berry
Chesapeake	B. L. Werner	R. L. Orndorff	D. H. Goldsborough	C. J. Lauter
Connecticut	E. A. Bell	W. N. MacKenzie	J. E. Riordan	D. W. Loiselle
Cuban	L. Plana Astienza	R. Garcia Montes	L. de Goicochea	L. H. Daniel
Florida	J. R. Kelly	H. T. Skaggs	C. H. Stanton	J. G. Simmons
Illinois	H. R. Frye	J. C. Vaughn	K. A. Steel	D. W. Johnson
Indiana	J. L. Ford Sr.	J. B. Wilson	H. A. Kerby	C. H. Canham
Intermountain	C. W. Wilson	W. C. Hague	E. J. Fjeldsted	M. W. Snell
Iowa	M. K. Tenny	H. F. Seidel	F. L. Wehrle	W. E. Bjork
Kansas	R. H. Hess	R. L. Chandler	O. R. Green	H. W. Badley
Kentucky-Tenn.	J. J. Davis	J. D. Boxley	L. H. Clouser	H. F. Mount
Michigan	H. O. Self	Tony Eikey	Gerald Remus	T. L. Vander Velde
Missouri	W. B. Schworm	F. E. Dolson	G. F. Ferrel	W. A. Kramer
Montana	Kurt Wiel	E. R. Waldo	F. B. Taylor	A. W. Clarkson
Nebraska	G. H. Beard	R. E. Arraj	G. H. Allen	J. J. Rossbach Jr.
New England	K. R. Kennison	A. J. Minkus	W. H. McGinness	R. M. Soule
New Jersey	R. E. Bonyun	P. E. Pallo	G. L. E. Linn	A. F. Pleibel
New York	J. M. Diven	C. M. Taylor	E. J. Clark	Kimball Blanchard
North Carolina	J. R. Purser Jr.	L. P. Bloxam	J. H. Henderlite	T. Z. Osborne
North Central	M. D. Lubratovich	W. J. Bell	Paul Buccowick	C. A. Flack
Ohio	M. W. Tatlock	Franklin Ruck	R. R. Deem	J. H. Bass
Pacific Northwest	W. H. Berkeley	A. H. Perry	Ray Struthers	F. D. Jones
Pennsylvania	S. S. Baxter	H. E. Beckwith	S. S. Baxter	L. S. Morgan
Rocky Mountain	J. O. Jones	Ernest Martinez	E. B. Ambler	H. F. Kepner
South Dakota	J. D. Davenport	W. P. Wells	Don Wessell	J. D. Bakken
Southeastern	C. C. Lanford	O. M. Fuller	M. E. Henley	N. M. deJarnette
Southwest	J. E. Williams	G. T. Kellogg	W. R. Hardy	L. A. Jackson
Virginia	W. B. Harman	J. B. Ferguson	J. G. Jones	E. H. Ruehl
West Virginia	D. H. Clark	Edward Shroyer	J. S. Hugart	H. W. Hetzer
Wisconsin	O. J. Muegge	E. W. Becker	J. H. Kuranz	Harry Breimeister

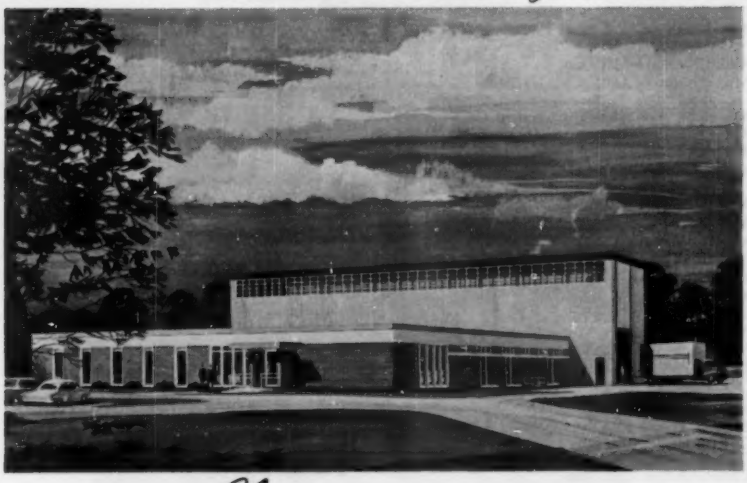
Directors Representing the Water and Sewage Works Manufacturers Assn.

E. E. Alt R. V. Ford J. A. Frank

Officers of the Divisions

Division	*Chairman*	*Vice-Chairman*	*Secretary*
Water Distribution	H. J. Graeser Jr.	J. G. Carns Jr.	A. H. Rice
Water Purification	H. E. Hudson Jr.	J. M. Sanchis	A. H. Ullrich
Water Resources	R. W. Morse	L. M. Miller	I. E. Anderson
Water Works Management	Gerald Remus	C. W. Wilson	John Copley

LOCK JOINT PIPE COMPANY *Proudly Presents*



ITS *New*, LARGER AND IMPROVED
RESEARCH AND DEVELOPMENT CENTER

Although Lock Joint Pipe Company has maintained its own research and testing laboratory for many years, the Company's growth and insistence on even higher quality products and improved manufacturing techniques have demanded the expansion of these facilities. For this reason it has erected a new research center featuring the latest equipment and staffed with scientists, engineers and trained technicians.

The members of the Research and Development Division, housed in this new half-million dollar center, stand guardian over the high quality of all present Lock Joint products and institute and evaluate future product developments. For it is the Company's firm conviction that only by strict quality control can its products' superiority be maintained, and only through the development of even better materials and more efficient manufacturing techniques can it retain its position at the head of its field.

LOCK JOINT
CONCRETE PIPE

LOCK JOINT PIPE CO.
East Orange, New Jersey

Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich.
Hartford, Conn. • Kansas City, Kan. • Perryman, Md. • St. Paul, Minn. • Winter Park, Fla.
Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

LIST OF ADVERTISERS

	P&R PAGE
Ace Pipe Cleaning, Inc.	—
Alabama Pipe Co.	—
Allied Chemical Corp., General Chemical Div.	91
Allied Chemical Corp., Plastics & Coal Chemicals Div.	—
Allis-Chalmers Mfg. Co.	—
Allis-Chalmers Mfg. Co., Hydraulic Div.	67
American Agricultural Chemical Co.	38
American Cast Iron Pipe Co.	79
American Concrete Pressure Pipe Assn.	20, 21
American Cyanamid Co., Process Chemicals Dept.	93
American Hard Rubber Co.	—
American Pipe & Construction Co.	27
American Well Works	—
Anaconda American Brass Co.	35
Andrich Water Specialty Co.	—
Anthracite Equipment Corp.	—
Aqua Survey & Instrument Co.	—
Armco Drainage & Metal Products, Inc.	87
Atlas Asbestos Co. Ltd.	—
Badger Meter Mfg. Co.	—
Bailey Meter Co.	—
Bethlehem Steel Co.	—
B-I-F Industries, Inc.	5
Buffalo Meter Co.	59
Calgon Co.	—
Calmet Meter Div., Worthington Corp.	63
Carborundum Co., The	—
Carus Chemical Co.	—
Cast Iron Pipe Research Assn., The	12, 13
Centriline Corp.	—
Chain Belt Co.	—
Charles Machine Works, Inc.	—
Chicago Bridge & Iron Co.	71
Clow, James B., & Sons	7
Cochrane Corp.	—
Darley, W. S., & Co.	40
Darling Valve & Mfg. Co.	45
De Laval Steam Turbine Co.	81
DeZurik Corp.	—
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	—
Eddy Valve Co.	7
Eimco Corp., The	—
Electro Rust-Proofing Corp.	15
Ellis & Ford Mfg. Co.	—
Fairbanks, Morse	—
Fiese & Firstenberger	—
Filtration Equipment Corp.	—
Fischer & Porter Co.	69
Flintkote Co., The, Orangeburg Div.	—
Ford Meter Box Co., The	22
Foxboro Co.	—
Gamon Meter Div., Worthington Corp.	77
General Chemical Div., Allied Chemical Corp.	91
General Filter Co.	—
Glenfield & Kennedy	49
Golden-Anderson Valve Specialty Co.	—
Graver Tank & Mfg. Co.	43
Graver Water Conditioning Co.	—
Hagan Chemicals & Controls, Inc.	18
Halliburton Co.	—
Harco Corp.	—
Hays Mfg. Co.	46
Hersey-Sparling Meter Co.	85
Hungerford & Terry, Inc.	80
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	29
Inertol Co., Inc.	—
Infilco Inc.	33
International Salt Co., Inc.	57
Iowa Valve Co.	7
Johns-Manville Corp.	Cover 4
Jones Chemicals, Inc.	10
Keasbey & Mattison Co.	—
Kennedy Valve Mfg. Co., The	26
Klett Mfg. Co.	42
Koppers Co., Inc.	24
LaMotte Chemical Products Co.	—
Layne & Bowler, Inc.	41
Leopold, F. B., Co.	9
Lock Joint Pipe Co.	3
M & H Valve & Fittings Co.	73
Martin, Robert E.	40
Marathon Electric Mfg. Corp.	—
Millipore Filter Corp.	—
Monterey Sand Co.	—
Morgan Steel Products, Inc.	—
Mueller Co.	39
Multi-Metal Wire Cloth Co., Inc.	—
Nalco Chemical Co.	—
National Power Rodding Corp.	11
National Tank Maintenance Corp.	86
National Water Main Cleaning Co.	89
Neptune Meter Co.	30
Northern Gravel Co.	48
Olin Mathieson Chemical Corp.	25
Orangeburg Mfg. Co., Div. of The Flintkote Co.	—
Ozark-Mahoning Co.	—
Peerless Pump Div.	37
Pelton Div., Baldwin-Lima-Hamilton	—
Permutit Co.	—
Philadelphia Quartz Co.	76
Photovolt Corp.	19
Pilot Mfg. Co.	68
Pittsburgh-Des Moines Steel Co.	—
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	94
Plastics & Coal Chemicals Div., Allied Chemical Corp.	—
Pollard, Jos. G., Co., Inc.	14
Portland Cement Assn.	—
Pratt, Henry, Co.	—
Preload Co., Inc.	—
Pulsation Controls Corp.	86
Reilly Tar & Chemical Corp.	47
Robinson Pipe Cleaning Co.	—
Rockwell Mfg. Co.	94
Rohm & Haas Co.	65
Ronald Press Co.	—
Ross Valve Mfg. Co.	—
Servicised Products Corp.	—
Simplex Valve & Meter Co.	23
Smith, A. P., Mfg. Co., The	61
Southern Pipe Div. of U.S. Industries	—
Steel Plate Fabricators Assn.	75
Stuart Corp.	—
Tennessee Corp.	—
Trinity Valley Iron & Steel Co.	83
U.S. Pipe & Foundry Co.	16, 17
University of Chicago Press	—
Vulcan Materials Co.	—
Wachs, E. H., Co.	—
Walker Process Equipment, Inc.	—
Wallace & Tiernan Inc.	28
Wheeler Mfg. Corp.	84
Wheeler, C. H., Mfg. Co.	—
Wiley, John, & Sons, Inc.	—
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	—
Worthington Corp	—

Directory of Professional Services—pp. *50-56 P&R*

POSITIVE CONTROL OF MATERIALS IN MOTION B·I·F METERS FEEDERS CONTROLS

SAVE LIME and TIME!

B·I·F Omega PUG MILL SLAKER . . . 100% EFFECTIVE AT ALL RATES . . . INSURES COMPLETELY SLAKED, HOMOGENEOUS MIXTURE!

- Most advanced, performance-proved slaker available . . . offers 20:1 range . . . maximum capacities of 1000 and 4000 lbs./hr.
- Automatic start up . . . completely unattended operation.
- Progressive zone slaking . . . prevents short circuits throughout slaking cycle.
- Positive water ratio control at all rates . . . without operator checks.
- Continuous grit removal . . . constant vapor removal . . . console mounted controls.
- Simple rugged design for low maintenance . . . cold water slaking eliminates need for hot water and heat exchangers.

B·I·F Industries

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

Many other exclusive design features . . . request Bulletin 0042.20-1 for complete details. Write **B-I-F Industries, Inc., 365 Harris Avenue, Providence 1, R. I.**

Plan now for

AWWA ANNUAL CONFERENCE

Detroit, Mich. June 4–9, 1961

Coming Meetings

AWWA SECTIONS

Spring 1961

Feb. 1–3—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Chester H. Canham, State Board of Health, 1330 W. Virginia St., Indianapolis.

Mar. 16—New England Section, at Statler-Hilton Hotel, Boston, Mass. Secretary, Ralph M. Soule, San. Engr., State Dept. of Public Health, Boston, Mass.

Mar. 22–24—Illinois Section, at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Apr. 5–6—West Virginia Section, at West Virginian Hotel, Bluefield. Secretary, Hugh W. Hetzer, Design & Construction Dept., Union Carbide Chemicals Company, Box 8361, South Charleston.

Apr. 6–8—Montana Section, at Placer Hotel, Helena. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

Apr. 11–13—New York Section, at Statler-Hilton Hotel, Buffalo. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 22–22 Jackson Ave., Long Island City 1.

Apr. 12–14—Kansas Section, at Baker Hotel, Hutchinson. Secretary, Harry W. Badley, Representative, Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 14—California Section, at Biltmore Hotel, Santa Barbara. Secretary, Frank F. Watters, Hydr. Engr., State Public Utilities Com., State Bldg., Civic Center, San Francisco.

Apr. 19–21—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, Joseph J. Rossbach, Metropolitan Utilities, 18th & Harney Sts., Omaha.

Apr. 20–22—Arizona Section, at San Marcus Hotel, Chandler. Secretary, A. D. Cox, Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

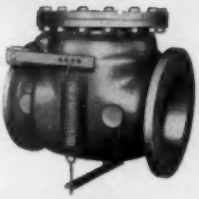
Apr. 23–26—Southeastern Section, at Poinsett Hotel, Greenville, S.C. Secretary, N. M. deJarnette, 96 Poplar St., N.W., Atlanta, Ga.

(Continued on page 8)

EDDY New Improved Products Meet Modern Needs

EDDY Fire Hydrant

- Improved, streamlined, modernized
- Optional break-flange
- Large diameter barrel
- New self-sealing main valve packing
- Requires no lubrication
- Opens *with* pressure
- Closes *against* pressure
- Underwriters' listed
- Standardized, interchangeable parts

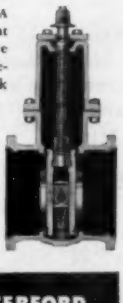


EDDY Check Valves

Completely new designs of horizontal swing check valves are available in sizes from 4 through 12 inches. They operate dependably in either vertical or horizontal positions and incorporate construction features which provide unusual flexibility of operation. These valves may be converted in the field from plain to single- or double-lever operation to meet changing requirements. Other check valves up to 24 inches.

EDDY Gate Valves

In addition to the regular line of EDDY Taper Seat AWWA gate valves, EDDY now offers a newly designed parallel seat AWWA gate valve in sizes through 12 inches. This valve has been specifically engineered to provide long, trouble-free service. Working parts are designed with heavy, thick section and large seating surfaces for dependable operation and improved wearing qualities. The valve has two-point, free-floating wedging for minimum friction and maximum operating ease. Other AWWA gate valves are available through 48 inches.



Whatever your waterworks requirements, it will pay you to have full information on the complete EDDY *line of valves and hydrants.*

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons, Inc.
WATERFORD NEW YORK

Coming Meetings

(Continued from page 6)

Apr. 26–29—Pacific Northwest Section, at Empress Hotel, Victoria, B.C. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane, Wash.

Jun. 1–3—Canadian Section, at Prince Edward Hotel, Windsor, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Jun. 20–22—Pennsylvania Section, at Galen Hall Hotel, Wernersville. Secretary, L. S. Morgan, 413 First National Bldg., Greensburg.

Fall 1961

Sep. 11–13—Kentucky-Tennessee Section, at Brown Hotel, Louisville, Ky. Secretary, Harold F. Mount, Gen. Mgr., Preston Street Road Water Dist. No. 1, 5400 Preston Hwy., Louisville, Ky.

Sep. 13–15—New York Section, at Saranac Inn, Saranac Lake. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City 1.

Sep. 13–15—North Central Section, at Hotel Lowry, St. Paul, Minn. Secretary, Carl A. Flack, Registrar, Water Dept., 216 City Hall, St. Paul 2, Minn.

Sep. 20–22—South Dakota Section, at Sheraton-Johnson Hotel, Rapid City. Secretary, J. Darrel Bakken, Div. of San. Eng., State Dept. of Health, Pierre.

Sep. 27–29—Wisconsin Section, at Hotel Schroeder, Milwaukee. Secretary, Harry Breimeister, Bureau of Engineers, Room 607 Municipal Bldg., 841 N. Broadway, Milwaukee.

Oct. 1–3—Missouri Section, at Kentwood Arms Hotel, Springfield. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Bldg., Jefferson City.

Oct. 4–6—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, Edward H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond 20.

Oct. 8–11—Alabama-Mississippi Section, at Buena Vista Hotel, Biloxi, Miss. Secretary, Ernest Bryan, Southern Sales Mgr., McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

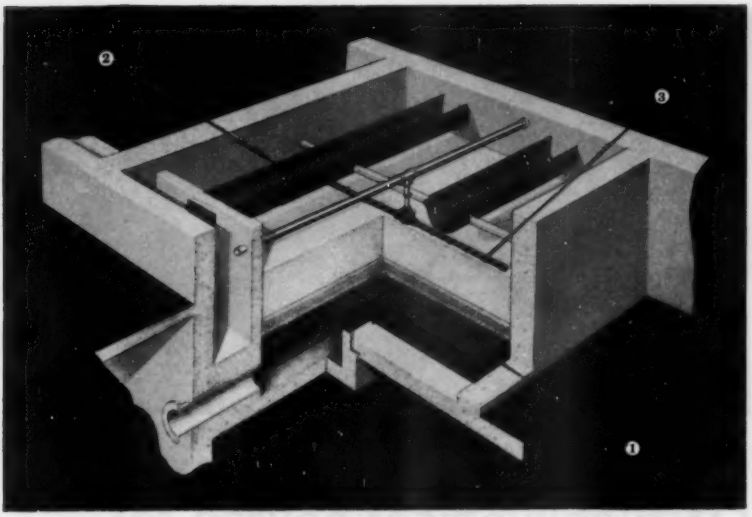
Oct. 15–18—Southwest Section, at Hilton Hotel, San Antonio, Tex. Secretary, L. A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 18–20—Iowa Section, at Roosevelt Hotel, Cedar Rapids. Secretary, Wilbur E. Bjork, Service Supt., Des Moines Water Works, 1003 Locust St., Des Moines.

Oct. 25–27—California Section, at Hotel Senator, Sacramento. Secretary, Frank F. Watters, Hydr. Engr., State Public Utilities Com., State Bldg., Civic Center, San Francisco.

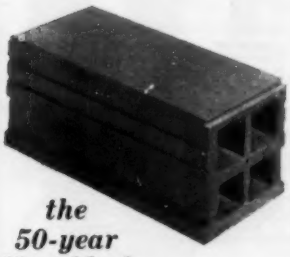
Oct. 25–27—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, J. H. Bass, Henry P. Thompson Co., 4866 Cooper Rd., Cincinnati.

Nov. 1–3—Chesapeake Section, at Emerson Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St. N.W., Washington, D.C.



FROM TOP TO BOTTOMS . . . SPECIFY LEOPOLD

- Leopold Glazed Tile Filter Bottoms.
- Leopold Fiberglass-Reinforced Plastic Wash Troughs.
- Leopold Rotary Surface Washers.



the 50-year filter block

Now you can specify an entire non-corroding filter installation from Leopold . . . your experienced source of supply. For lowest "over-the-years" cost, choose performance-proved Leopold glazed tile filter bottoms, built to last at least half a century. Tough Leopold fiberglass-reinforced wash troughs require no painting or other expensive maintenance. And new Leopold self-propelled rotary surface washers complete the package with a dependable product that's guaranteed for five years against mechanical and functional defects. Leopold filter plant equipment is used in thousands of plants throughout the country, on both new and rehabilitation projects. Choose these time-tested products by Leopold . . . for your complete filter needs. Write today for facts and figures.

Leopold

F. B. LEOPOLD CO., INC., Zelienople, Pa.

Exclusive Canadian Representative:
W. J. Westaway Co., Ltd., Hamilton, Ontario

F. B. LEOPOLD CO., INC., Zelienople, Pa.

☐ Please send literature on Leopold Glazed Tile Filter Bottoms.
☐ Please send literature on complete line of Leopold products.

Name _____

Affiliation _____

City _____ Zone ____ State _____

AT ELEVEN PLANTS ACROSS THE COUNTRY, Jones receives tank cars of Chlorine, repackages it in cylinders and 1-ton tanks, makes quick deliveries to users in area.

ONE convenient source for all your chlorine needs

Get chlorine products any way you want them, in any amount you need, from just *one* dependable source—Jones Chemicals.

It eliminates hop-scotch buying of liquid chlorine, calcium hypochlorite, or sodium hypochlorite, and enables you to plan your needs and deliveries . . . avoid excess storage. Eleven Jones plants, strategically located across the U.S., stand ready to deliver chlorine products *when you need them.*

Get chlorine in any amount—from 16-lb. cylinders to 1-ton tanks. Jones packages high-purity chlorine in less than carload lots. You pick the size and type of container you need.

Our trained technical staff will be glad to help you with your chlorine problems. Write for information and prices, or contact the Jones plant nearest you.

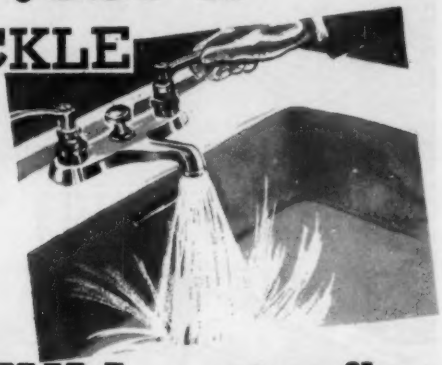
John Wiley

JONES CHEMICALS, INC.

"A good name in chemicals"

Beech Grove, Ind. Charlotte, N. C. Jacksonville, Fla. St. Petersburg, Fla.
Caledonia, N. Y. Erie, Pa. North Miami, Fla. Torrance, Calif.
Hudson, Wis. Wyandotte, Mich. Warwick, N. Y.

NOT JUST A TRICKLE



but FULL water flow

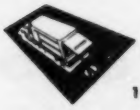
- UP TO 95% RECOVERY
- POWER EQUIPMENT
- EXPERIENCED MEN
- IRON-CLAD GUARANTEE

Cut your maintenance costs and add to your pipe capacity with N.P.R.C.'s contract service. We guarantee to clean your pipes to 95% of their original capacity, and to do the job to your complete satisfaction or it costs you nothing. Annoying "rusty" water is also removed by our patented cleaning methods. Investigate this service . . . send for the free booklet, "Power," which gives the facts on pipe cleaning the modern contract way.

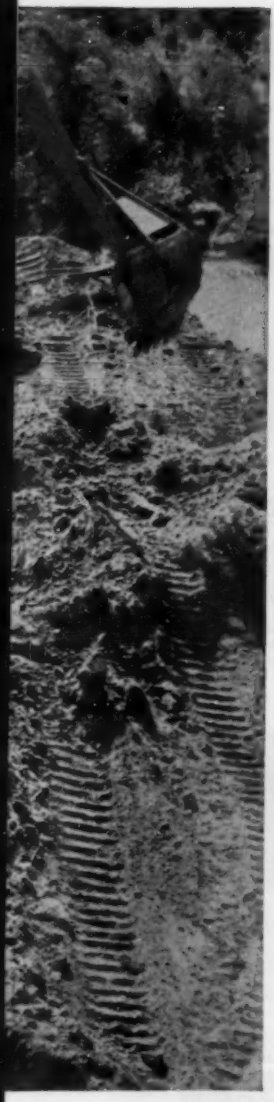
NEW! PIPE INSPECTIONS BY CLOSED-CIRCUIT TV!

Tremendous savings on pipe repair through TV inspection. Available for pipes 4" diameter up. Write or call now for complete details.

CALL COLLECT
MOnroe 6-7700



NATIONAL POWER RODDING CORPORATION
1000 SOUTH WESTERN AVENUE · CHICAGO 12, ILLINOIS



WILL PERFORM FOR A CENTURY WITH A RIVER ON ITS BACK

At left, you see a length of cast iron pipe being installed under the Floyd River in Iowa. This is part of a water feeder main which will reinforce the existing water supply system.

Despite the severe conditions of a river overhead, the inherent ruggedness of cast iron pipe promises at least a century of trouble-free performance, and rarely requires repairs or replacement.

And cast iron pipe's cement lining assures a continued full flow of water year after year. It's no wonder that more than 90% of the pipe used for water supply systems in our 50 largest cities is cast iron pipe!

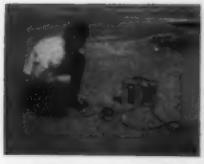
CAST IRON PIPE RESEARCH ASSOCIATION
Thos. F. Wolfe, Managing Director
3440 Prudential Plaza, Chicago 1, Illinois

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

M-Scope "Master" Electronic Witch
Leak Survey Instrument and Pipe Locator

The transistorized "MASTER" Leak Detector—Pipe Finder Combination is the first dual purpose instrument with separate and independent leak detector and pipe finder circuits. Now you can have two instruments in one without any compromise in performance. The "MASTER" Leak Detector—Pipe Finder incorporates the very latest advances in electronic construction and circuitry in addition to having an exceptionally long battery life. An ideal instrument for any Water Department.



Finding a leak under pavement

Locating a leak at the valve

Location of dead ends

Locating a service

Write for information, demonstration or trial.

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

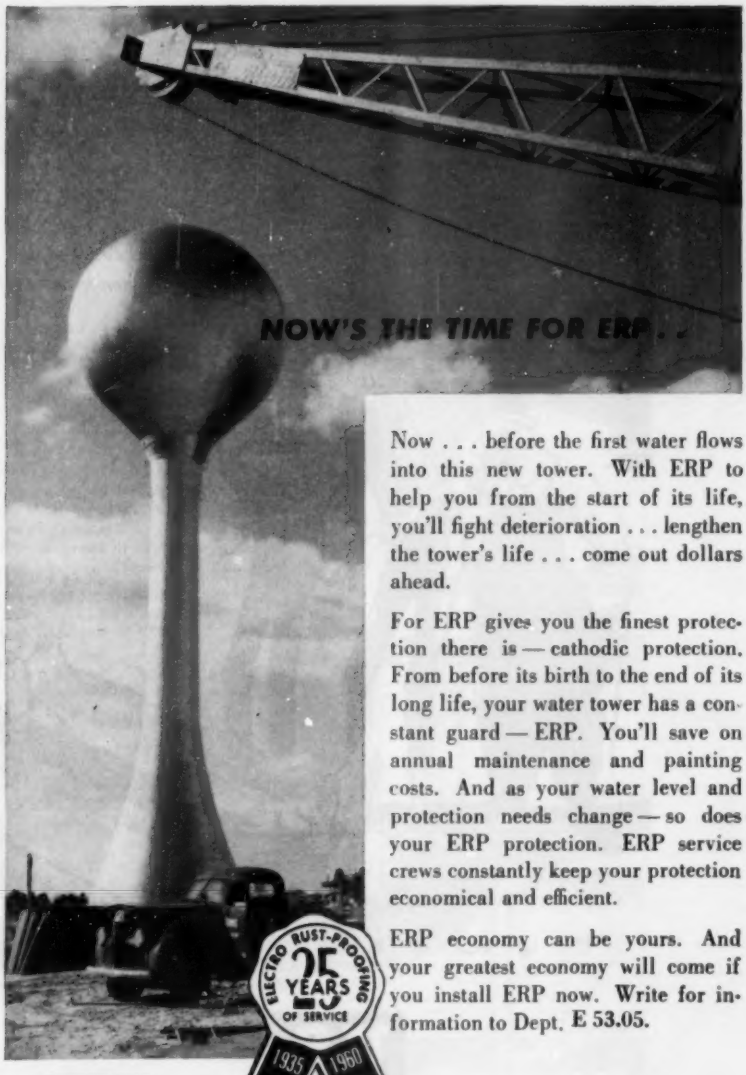
PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD ... It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 904 Peoples Gas Building, Chicago, Illinois
333 Candler Building, Atlanta, Georgia



Now . . . before the first water flows into this new tower. With ERP to help you from the start of its life, you'll fight deterioration . . . lengthen the tower's life . . . come out dollars ahead.

For ERP gives you the finest protection there is — cathodic protection. From before its birth to the end of its long life, your water tower has a constant guard — ERP. You'll save on annual maintenance and painting costs. And as your water level and protection needs change — so does your ERP protection. ERP service crews constantly keep your protection economical and efficient.

ERP economy can be yours. And your greatest economy will come if you install ERP now. Write for information to Dept. E 53.05.

ERP CATHODIC PROTECTION SINCE 1935

ELECTRO RUST-PROOFING CORP.

A SUBSIDIARY OF WALLACE & TIERNAN INC.

30 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CABLE: ELECTRO, NEWARK, N. J.

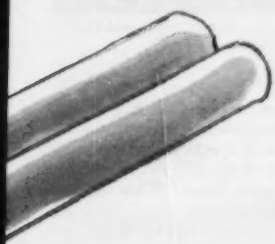
U.S. cast iron PIPE FOR WATER, SEWERAGE A

almost as easy!

n their enthusiasm our hillbilly pals sometimes xaggerate.

yton Joint® pipe isn't quite as easy to install as alling off a log. But almost! One simple accessory nd you're in business! No bell holes. No nuts, bolts, ots or ladles. Fewer weather delays, too. Tyton® an be installed in rain or wet trench, if need be. And even inexperienced crews can lay it.

Vant more working days, less time, trouble in the rench? Tyton Joint pipe is your answer. Get the facts. Call or write today.

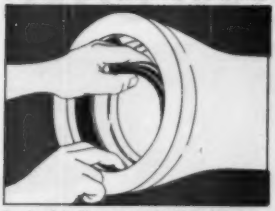


U.S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama
A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe.

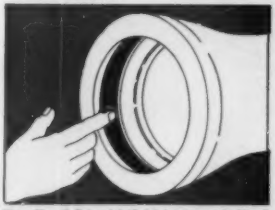
USTRIAL SERVICE CAST IRON

TYTON®

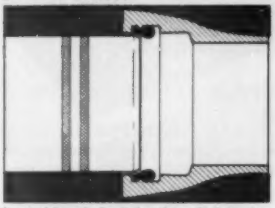
ONLY FOUR SIMPLE ACTIONS



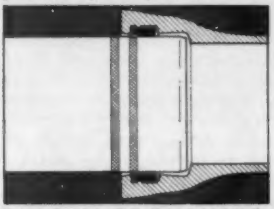
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?

Florida City Water Plant

SAVES TIME AND MONEY WITH HAGAN COAGULANT AID

Robert Ankney inspects filter

Coagulant Aid Feeder

Vero Beach, Florida, Water Treatment Plant

Quick case history—reading time 57 seconds

The City of Vero Beach, Florida, has a 6 mgd softening plant that draws water from six shallow wells. The plant formerly used activated silica as an aid to coagulation. While results were satisfactory, the plant investigated other coagulant aids in the hope of increasing the efficiency of their operation. After exhaustive laboratory tests and plant trials, Hagan Coagulant Aid #7 was adopted as it is easy to apply, requires less storage space and only a minimum of supervision. A feed rate of only ½ ppm was set up for the Hagan Aid.

A recent test showed that filters can be operated at 10% above rated capacity for 230 hours with only a 4-foot loss of head; normal filter runs are of 200 hours duration.

Another saving showed up during a recent expansion, when Gee & Jensen, Consulting Engineers, incorporated feeding equipment specifically designed for Hagan Coagulant Aid #7 into their plans for the new plant. This equipment cost approximately one-fourth as much as equipment that would be needed for activating silica.

Hagan Coagulant Aids are non-toxic, easy to handle, and produce a large, tough floc that speeds settling time and reduces carryover. They may be dry-fed or slurry-fed as desired. Write for Bulletin HSP 919 for information on the complete line of Hagan Coagulant Aids.

HAGAN

CHEMICALS & CONTROLS, INC.

HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO.; HALL LABORATORIES; BRUNER CORP.

PHOTOVOLT
pH Meter Mod. 115

A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

$175

- SIMPLE IN OPERATION AND MAINTENANCE
- FAST AND DEPENDABLE IN SERVICE

Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters

PHOTOVOLT CORPORATION

95 MADISON AVENUE NEW YORK 16, N. Y.

Also: Multiplier Photometers, Exposure Photometers for Photomicrography, Hemoglobinometers, Glucometers, Polarimeters, Foot-Candle Meters, Interference Filters, Mirror Monochromators

Concrete Pressure Pipe...

MEANS MORE WATER FOR MORE YEARS AT LESS COST

In this era of exploding population, pipelines must carry more water to satisfy growing domestic and industrial demands. Concrete Pressure Pipe answers this problem with an inherent high coefficient that assures maximum carrying capacity.

Because virtually ageless Concrete Pressure Pipe resists corrosion and tuberculation, its initial high carrying capacity is normally unimpaired over the years, providing maximum volume as demands increase.

Yet Concrete Pressure Pipe's premium service is available at low first cost, it is economically installed and it continues its saving ways for generations in lower pumping costs and negligible maintenance requirements.

In planning for the future, remember . . . you'll get *more* for *longer* for *less* with Concrete Pressure Pipe.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street, Chicago 1, Illinois

FOUR reasons why Ford covers offer greater protection and convenience for every meter box installation . . .

1 2 3 4

DOUBLE LID METER BOX COVERS

Designed to provide the utmost in frost protection for pit meters, the "Wabash Cover" has a total depth of 9½ inches. Its extra depth, sloping skirt and 4" dead-air space between inner lid and top lid minimize heat loss from the top of the meter setting.

These covers can be provided in "standard weight" for ordinary service, or "extra heavy," when the lid will be exposed to traffic.

SINGLE LID METER BOX COVERS

Designed for sidewalk or lawn installation, Ford "Type A" covers are made for 15", 18", 20" and 21" meter boxes. Lids are inset.

Lifter Worm lock used on these covers helps speed meter readings. Screw jack action plus automatic attachment of the key to the bolthead make lid removal a simple, clean task.

MONITOR COVER

Designed for use on large tile — where a large lid opening is desirable — "Monitor Covers" consist of 1) a flange casting to fit on the tile, 2) a ring centered in place on the flange by a circular bead, and 3) a top lid with Lifter Worm Lock.

These covers can be used for 1½" and 2" meters . . . or for two or more smaller meters. Lid size permits meter reader to enter setting if necessary.

HINGED LID

Designed for same installations as other single lid covers, "Type X cover" features hinge effect so lid can simply be leaned back instead of lifted off while meter is read.

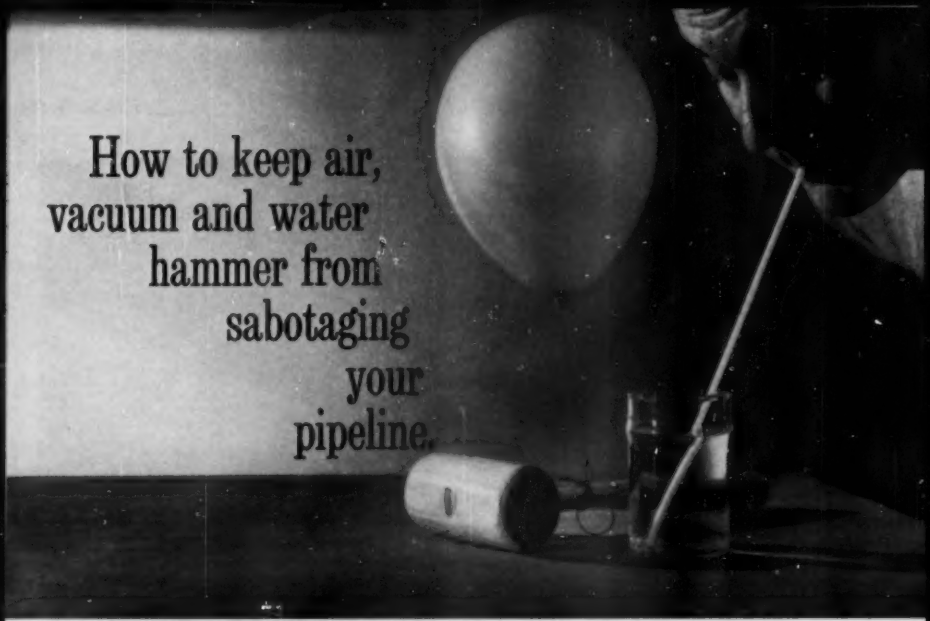
Simple, ingenious lugs in the frame casting pivot the lid and support it. Thus, if desired, it can also be completely lifted off.

For more information, write . . .

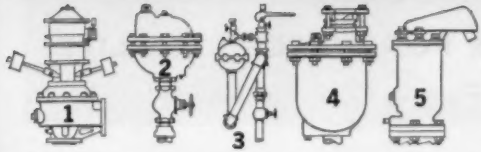
FORD

FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana



How to keep air, vacuum and water hammer from sabotaging your pipeline.



A brief Simplex guide to pipeline economy

1. Prevents water hammer: Type CCAV Controlled Closing Air Valve protects against damaging effects of surge and water hammer. Combines functions of an air inlet valve (vacuum breaker) and a controlled closing unit (to prevent sudden water stoppage and subsequent water hammer). 4" and 6" sizes. Capacities from 575 to 5980 gpm. Send for Bulletin 1225.

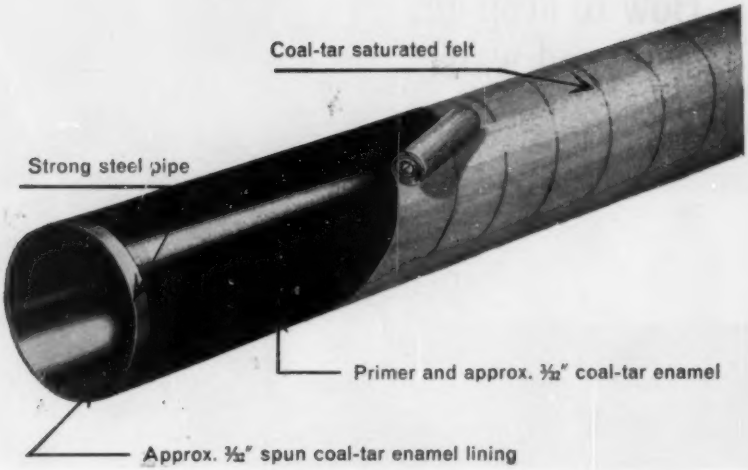
2. Removes excess air: Type AGFD Automatic Air Release Valve prevents stoppages due to air-lock at high points in line. Has large discharge capacity, excess power to insure opening of the valve against high internal pressure. Can be equipped to hold vacuum, preventing re-entry of air into pipeline through valve. Furnished with 2", 1½" or 1" inlet diameter. Standard valve operates to 250 psig—special to 300 psig. For details, get Bulletin 1206.

3. Protects sewage pipelines: Type "B" Air Release Valve, special for lines carrying sewage or sludge, removes entrained air and gases. Special trap catches sludge, prevents fouling of air release valve. Relatively simple back-flushing cleans out this trap, maintains top efficiency and protection. Valve itself is same as Type AGFD. Details are in Bulletin 1206.

4. Provides three functions: Type AV Air Release and Air Inlet Valve performs three operations, combines great protection and single-unit economy: (1) Automatically releases accumulated air, (2) admits air to break vacuum, and (3) vents pipeline to permit escape of air when filling system with water. Standard units operate to 150 psi. For full details, send for Bulletin 1205.

5. Breaks vacuums: Type VAC Air Inlet Valve solves two serious pipeline problems: possible collapse of pipelines due to formation of vacuums—and stoppage of flow, caused by air binding when lines are being filled. Standard units have 4" to 10" inlet diameters, can be assembled in groups to do the work of one large, expensive valve. For 16 pages of detailed information, get Bulletin 1202.

SIMPLEX®
VALVE AND METER COMPANY
a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania



BEST FORMULA FOR WATER LINE LIFE

Strong Steel Pipe + Coal-Tar Enamel

The superior flow characteristics of steel water pipe lined with Bitumastic® 70-B AWWA coal-tar enamel are well-known. Smoothest of all spun pipe linings, coal-tar enamel also gives long-term protection against tuberculation and incrustation, causes of reduced flow capacity.

And when the *outside* of your water line is completely protected by Bitumastic coal-tar enamel, moisture can't reach the metal, so corrosion can't start. For coal-tar enamel has superior resistance to water penetration and absorption, and higher electrical resistivity underground: has been proved by actual experience to provide better protection than any other coating. Utilization of the outstanding strength of steel pipe guarded by coal-tar enamel adds up to true water line durability.

When you invest in a water line, it makes good economic sense to specify the finest: steel pipe, lined and coated with Bitumastic coal-tar enamel. Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pennsylvania.

KOPPERS

BITUMASTIC

ENAMELS

another fine product of COAL TAR

District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh, Woodward, Ala.

Control water alkalinity, reduce acidity... with handy PH-Plus blocks. Dry and dustless, with no caking, no waste from spilling. They dissolve slowly, last longer, assuring a more accurate, more constant feed with no zig-zag alkalinity results. Try economical PH-Plus soon, and learn how easy it is to control pH of water. Packed in 100-lb. bags. Write for further information.

OLIN MATHIESON CHEMICAL CORPORATION
Chemicals Division • Baltimore 3, Maryland

perfect pH control...

PH-PLUS

PH-Plus® is a trademark

4828

Olin Mathieson Chemical Corporation
Chemicals Division, Mathieson Building
Baltimore 3, Maryland

☐ I'd like more information on PH-Plus
☐ I'm interested in distributing PH-Plus

Name.....

Address.....

City.....State.....

KENNEDY VALVE has a complete line of A.W.W.A. Standard Gate Valves . . .

. . . that conform to A.W.W.A. specifications in all respects

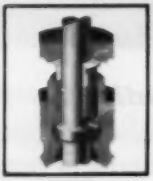
FIG. 50
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Bell Ends

FIG. 571X
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Mechanical Joint Ends

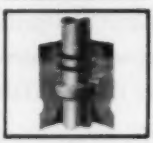
FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

FIG. 260
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

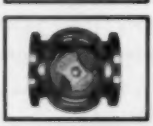
Construction features . . .



Conventional stuffing box
with adjustable gland has ample space for packing that conforms to Federal specification HH-P-106c. The bottom face of the stuffing box flange is faced smooth to form bearing surface for stem thrust collar.



O-Ring seals
once installed no adjustment of any kind is required. The top O-Ring is the dirt seal and the bottom O-Ring is the pressure seal.



Operating nut
is Higher Strength Cast Iron. The base flange, with arrow indicating direction to open, is shaped to permit access from ground surface to adjust gland nuts with an extension socket wrench.

KENNEDY A.W.W.A. Standard gate valves are designed specifically for use in water works systems. Conforming to A.W.W.A. Specifications, in several particulars these valves exceed these standards of strength and refinements of design.

While A.W.W.A. Specifications cover only bell end and flanged end non-rising stem valves, the KENNEDY line also includes outside-screw-and-yoke valves and a wide variety of pipe connections including: Bell Ends, Flanged Ends, Mechanical Joint Ends, Universal Pipe Ends, Asbestos Cement Pipe Ends, Screwed Ends, Ring-Tite Pipe Ends and Spigot Ends.

In addition to standard features, KENNEDY A.W.W.A. Valves have reduction gearing, gear cases, by-passes, indicators and rollers, tracks and scrapers available on 16" and larger sizes. Gearing is always furnished on 30" and larger valves.

KENNEDY VALVE MFG. CO.
ELMIRA, NEW YORK
VALVES
FIRE HYDRANTS

• WRITE TODAY FOR A.W.W.A. BULLETIN 561

• OFFICES AND WAREHOUSES •

CHICAGO — 1106-12 South Canal St., Chicago 7, Illinois
NEW YORK — 161 Sixth Avenue, New York 13, N. Y.
SEATTLE — 615 Western Avenue, Seattle 4, Washington
SAN FRANCISCO — 351 Tenth St., San Francisco 3, Calif.
ATLANTA — 486 Lakewood Circle S.W., Atlanta, Georgia
CINCINNATI — 5200 Este Avenue, Cincinnati 32, Ohio

• SALES OFFICES IN PRINCIPAL CITIES •

LONG-TERM ECONOMY

$A_s + A_y$ = FLEXIBLE DESIGN

When an engineer designs a complete water transportation system, he must give consideration to the differences in internal pressure caused by changes in elevation, hydraulic gradient, and many other varying operating conditions. American Concrete Cylinder Pipe offers a flexible design to accommodate these conditions through variations in the gauge of the steel cylinder, the diameter of the circumferential steel rod reinforcement, and the center-to-center spacing of the rod reinforcement to obtain the precise cross-sectional steel area required. ■ The cost of delivered water should be measured, not in terms of the initial investment for the system which transports it but in terms of the ultimate cost of that system. With the flexible design of American Concrete Cylinder Pipe, an engineer can obtain a system economical in ultimate cost and enduring in reliable performance. ■ An American sales engineer is ready to show you the advantage of flexible design and a resulting economy for your next project.

American Pipe and Construction Co. • Los Angeles • San Diego • Hayward • Portland
Bogota, Colombia / **American Concrete Pipe Co. (subsidiary)** • Phoenix • Albuquerque
A MEMBER OF THE AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

American PIPE AND CONSTRUCTION CO.

W&T COMPOUND-LOOP CONTROL

With automation by Wallace & Tiernan your chlorination system controls itself . . . needs almost no attention. With Compound-loop Control, the residual you select is maintained, no matter how much water flow or chlorine demand changes. You're always sure of water quality.

W&T Compound-loop Control means true process control. Because it analyzes the end result and feeds back information which monitors your chlorinator, Compound-loop Control successfully achieves a closed-loop system. This means an operating range of greater than 100 to 1, plus round-the-clock supervision without extra labor.

And you can control free or total residual . . . use electric, pneumatic, or variable vacuum signals. W&T Compound-loop Control can be tailored to the physical layout of your system, your flow-metering equipment, your plant hydraulics. You build or convert to automation with maximum convenience, minimum expense.

For more information, write Dept. S-141.05

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 52 • DECEMBER 1960 • NO. 12

Ground Water Recharge and Conservation

Panel Discussion

A panel discussion presented on May 16, 1960, at the Annual Conference, Bal Harbour, Fla.

Effects of Viscosity and Temperature

Richard T. Sniegocki

A paper presented by Richard T. Sniegocki, Dist. Geologist, Ground Water Branch, USGS, Little Rock, Ark.

STUDIES of artificial recharge through wells have been underway in the Grand Prairie region of Arkansas since 1953 (Fig. 1). The general plan of the studies involves carefully controlled experiments to determine the feasibility of artificial recharge using various types of wells and waters. The Army Corps of Engineers and the University of Arkansas are actively participating with USGS in these studies. These three agencies, which are primarily responsible for the experiments, have the assistance of the Arkansas State Health Department; the Arkansas Geological and Conservation Commission; the Stuttgart Chamber of Commerce; and other local agencies, companies, and individuals.

Two experimental wells have been constructed. The first well was gravel packed in a conventional manner, and the second well was sand packed with graded sand identical to that used in rapid sand filters. The sand-packed well is being used in tests now in progress.

Seventeen recharge tests have been made in Well 1, the first test using ground water and the others using surface water treated in various ways. Recharge with ground water was done to develop operational techniques to be used in later tests and to learn whether artificial recharge through a well could be accomplished successfully at a practical rate under favorable conditions. Approximately 3½ mil gal of water (11 acre-ft) was injected into the ground at an average rate of 512 gpm during the first test. A total of 10 mil gal of surface water was injected into the aquifer during the other

tests. The total time required for injection of the 10 mil gal was 16 days.

Four recharge tests have been completed with Well 2, and 7 mil gal of water have been injected into the aquifer. From results obtained during the earlier tests, it seemed advisable to make fewer variations in injection factors and longer test runs at lower rates of recharge. The total time required for actual injection of the 7 mil gal was 20 days.

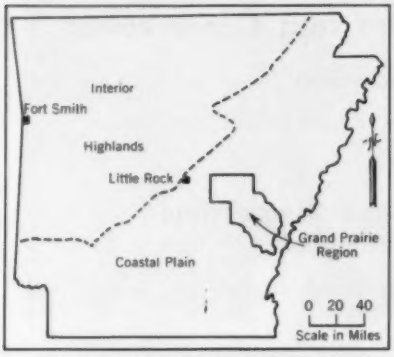


Fig. 1. Map of Arkansas Showing Grand Prairie Region

The broken line represents the division between the interior highlands and the coastal plain.

Viscosity and Temperature Observations

Reports concerning artificial recharge through wells mention many causes of clogging, but few attempt to evaluate the relative importance of the clogging factors. Few reports present data concerning the effects of water temperature and viscosity on recharge rates and other characteristics. Two recharge tests, in which the effects of water viscosity variations caused by differences in water temperatures were observed, are described as follows:

Test 12. Test 12, utilizing the gravel-packed recharge well, was started on Oct. 11, 1957. Surface water from a reservoir was treated with copper sulfate as a microorganism control measure, coagulated with alum, settled, chlorinated, filtered through a rapid sand filter, and injected into the recharge well. Injection was accomplished at an average rate of 502 gpm

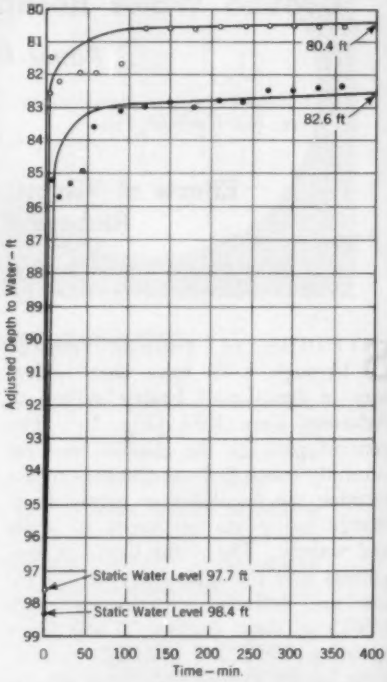


Fig. 2. Hydrographs of Recharge Well During Test 12 and Test 18

Test 12 (open circles): recharge rate, 502 gpm; buildup at 400 min, 17.3 ft; water temperature 66°F; specific capacity, 29.0 gpm/ft. Test 18 (solid circles): recharge rate, 310 gpm; buildup at 400 min, 15.8 ft; water temperature, 43°F; specific capacity, 19.6 gpm/ft.

for 6 hr. The turbidity of the injected water was measured by comparison of the amount of light transmitted through the sample with the amount scattered (Tyndall effect) by the sample. It averaged 2 ppm. The average temperature of the injected water was 66°F and ranged from 63° to 70°F.

Test 18. Test 18, made with the sand-packed well, was started on Jan. 29, 1959. Surface water, treated similarly to that used during Test 12, was injected at an average rate of 310 gpm for 28.5 hr. The turbidity of the injected water averaged slightly less than 3 ppm. Microorganism control was not quite as effective as it had been during Test 12; the count averaged 10 per milliliter, as compared to 8 in Test 12. The average temperature of the injected water was 43°F, thus providing a large temperature differential when compared to the temperature of water injected during Test 12. The temperature of the native ground water before the tests started was 65°F.

Results

There were only slight differences in the physical and chemical quality of the water injected during Tests 12 and 18, and these were caused by minor variations in the method of water treatment. None of these slight differences are considered sufficient to have caused appreciable changes in injection characteristics. The rise in water level (Fig. 2) observed during Test 12 was thought to be the result of hydraulic buildup, and none of the rise was attributed to clogging of the recharge well and aquifer. Figure 2 shows the changes in water level observed in the first 6 hr of recharge during Test 18. The shape of the hydrograph is very similar to that for Test 12, and no clogging of the well was suspected. If no plugging occurred during Test 18 and well characteristics were similar, the buildup in the recharge well after 400 min (6⅔ hr) should be less, because the recharge rate was 192 gpm less. Specific-capacity values should also reflect the rate difference. The value calculated at the higher rate should be less than that calculated at the lower rate, because of increased turbulence losses.

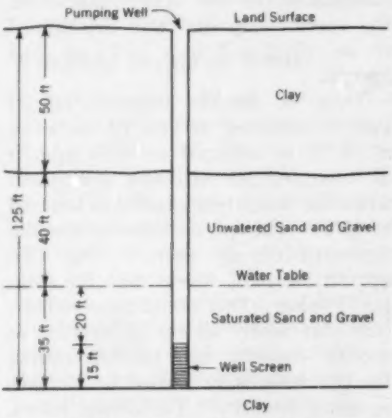


Fig. 3. Idealized Sketch of Typical Well in the Grand Prairie Region

For optimum results, recharge should be carried out when the injected water is the same temperature as, or warmer than, the native ground water.

This was not the case, however. The specific capacity at 400 min for 502 gpm was 9.4 gpm/ft higher than that calculated at 310 gpm.

Corrections for Temperature

Because no plugging of the well was indicated in either test, it was decided to see if viscosity differences caused by differences in water temperature might account for the different specific capacities and buildups. Temperature

corrections were made using the factors given by Wenzel,[1] or,

$$P_{(43)} = \frac{C_{t(66)}}{C_{t(43)}} P_{(66)}$$

in which P is the permeability at the indicated temperature and C_t is the correction factor for the indicated temperature (in degrees Fahrenheit). Specific capacity, if turbulence losses are neglected, is directly proportional to the permeability. Therefore, by substitution of the appropriate data, the specific capacity was determined to be $(0.92 \times 29.0) \div 1.31$, or 20.3 gpm/ft.

Thus, a specific capacity of 29 gpm/ft measured in Test 12 for water at 66°F is changed to 20.3 gpm/ft as corrected for viscosity differences when the water temperature is lowered to 43°F. The specific capacity actually measured during Test 18 was 19.6 gpm/ft, only 0.7 ft less than the computed value. This would seem to indicate that nearly all the differences in specific capacity and buildup during the two tests were caused by changes in water viscosity. Turbulence losses, minor variations of the two recharge waters, and observational errors may account for the 0.7-ft difference between the observed and corrected values.

Conclusions

In the Grand Prairie region, recharge would be most effective during the nongrowing winter season, when the available recharge water would be cold. If recharge through wells were to become a prevalent practice, it is conceivable that the average temperature of the water in the aquifer would be lowered. The following simplified discussion will serve to illustrate the problems arising under such conditions.

The hydrogeologic situation in the Grand Prairie region is shown in generalized form in Fig. 3. If the specific capacity of the well is 29 gpm/ft and the water level in the well is drawn down to the top of the screen, it would be theoretically possible to pump 580 gpm when the ground water has a temperature of 66°F. If the temperature of the ground water is lowered to 43°F, and if the same pumping conditions as outlined above are imposed on the well, an additional 10 ft of saturation will be necessary to produce 580 gpm. This means that the first 10 ft of rise in water level in the aquifer brought about by recharge with cold water will be of no practical value in increasing the quantity of water available. To effect a general rise of 10 ft in the Grand Prairie aquifer will require many recharge wells injecting a large quantity of water. Therefore, results of recharge will be optimum when the injected water is the same temperature as, or warmer than, the native ground water.

Reference

1. Wenzel, L. & Fishel, V. Methods for Determining Permeability of Water-Bearing Materials. Water Supply Paper 887, US Geological Survey, Washington, D.C. (1942).

Practices on the High Plains of Texas

—William L. Broadhurst—

A paper presented by William L. Broadhurst, Chief Hydrologist, High Plains Underground Water Conservation Dist., Lubbock, Tex.

The High Plains of Texas extend 300 mi southward from the Oklahoma Panhandle and 100 mi eastward from New Mexico, terminating at a bold escarpment. The plains embrace 35,000 sq mi, or 22,000,000 acres, of almost level, fertile soil, most of which is suitable for cultivation. Because the precipitation on the plains averages only 20 in. per year, irrigation is desirable to assure maximum crop production. There are no surface streams of consequence within the region; therefore, water for all municipal and industrial purposes and for large-scale irrigation is obtained exclusively from wells.

Source and Supply

Natural recharge to the ground water reservoir is from local precipitation, and, according to studies that have been made during the last 25 years by USGS, it ranges between $\frac{1}{10}$ and $\frac{1}{4}$ in. per year—somewhat less than 500,000 acre-ft—or 10 per cent of current annual withdrawals.

The quantity of ground water originally in storage beneath the plains, before the start of large-scale pumpage, was in the neighborhood of 400,000,000 acre-ft. Total pumpage from wells within the region during the 50-year period 1910–59 was about 50,000,000 acre-ft, of which 98 per cent was used for irrigation. By far the greater portion of the withdrawals was made during the single decade 1950–59, when annual pumpage increased to more than 5,000,000 acre-ft to irrigate more than 4,000,000 acres.

As a result of the rapidly increasing use of ground water for all purposes, the supply is being depleted. For the region as a whole, it is estimated that 10–12 per cent of the supply has been used, but in some areas concentrated pumpage has depleted the available supply by more than half.

Available Recharge Water

Approximately 10 per cent of the plains is within the drainage basins of the Canadian, Red, Brazos, and Colorado rivers; the remaining 90 per cent, or 20,000,000 acres, contributes surface runoff only into the thousands of saucerlike depressions or playa lakes that dot the plains. The depressions range in diameter from a few hundred feet to more than a mile and in depth from a few inches to more than 50 ft. The bottoms of many depressions contain 50 ft or more of clay and colloidal materials that are relatively impermeable. Consequently, such depressions hold water for months and practically all the water from the playa lakes is lost through evaporation.

Computations based on soil cover complex data from the Soil Conservation Service field office in Fort Worth, Tex., and the rainfall-runoff relationship in the SCS *Hydrology Guide* show that the average annual runoff from the High Plains' surface is about 0.85-in. This means the average runoff from each square mile is 45 acre-ft, and the annual runoff from the 20,000,000 acres which collects in the depressions is 1,400,000 acre-ft, several times more than the total natu-

ral recharge to the underground reservoir.

Artificial-Recharge Tests

The High Plains Underground Water Conservation District, which was created under state law, is of the local-option type and is both financed and governed by the inhabitants. The district directors and representatives are concerned primarily with the orderly development and provident use of the ground water. Soon after its creation, however, the district realized that salvaging the playa lake water involves problems in engineering, chemistry, biology, and economics. In many localities the costs required to salvage the water would unquestionably exceed current benefits; but the district also realized that if it waited until all the problems were solved, it would have waited too long. For this reason an active operational program, rather than a research program, was started to find practical methods whereby the lake water could be put to beneficial use.

In October 1953, the district sponsored a recharge well near a playa lake in southwestern Floyd County. The well was drilled with a hydraulic rotary rig to a depth of 377 ft, penetrating the full thickness of the water-bearing formation. Samples of the drill cuttings showed medium-grained sand at levels 127–152 ft, 168–198 ft, and 215–235 ft, and sand and gravel at 302–370 ft—a total of 142 ft of good water-bearing material. The hole was cased from top to bottom with 12-in. steel gas line which had torch-cut slots ½ in. wide and 14 in. long staggered around the pipe from 130 ft to the bottom. As the casing was set in the well, a packer was placed several feet below the land surface, and the annular space between the casing and the well bore was filled with cement to prevent water from rising outside the casing. A deep well turbine test pump was installed and the well was developed in the conventional manner by backwashing and pumping at approximately 1,100 gpm for several days. The pump was then removed. Underground pipe equipped with a control valve was laid from the low point in the lake to the well so water could flow into the well by gravity. The static water level in the well was 80 ft below the bottom of the lake.

After the recharge installation was completed, the first rain to produce significant runoff came on Jun. 2, 1955. Because of the colloidal material in the lake bed, the shallowness of the water, and wind action on the plains, the lake water remains muddy, and siltation was and still is a serious problem. The idea behind the program, however, was to develop simple facts regarding the feasibility of draining the lakes merely by drilling recharge wells. Two days after the lake filled, the valve was opened and water flowed into the well at an initial rate of 1,050 gpm. After continuous recharge for various periods of time the rates of input were as follows: 12 hr, 630 gpm; 24 hr, 540 gpm; 48 hr, 483 gpm; 72 hr, 415 gpm; and 192 hr (8 days and nights) less than 200 gpm. During the 8-day period the well took 4.2 mil gal (approximately 13 acre-ft), but analyses of the water showed that more than 300 cu ft of suspended matter had entered the well.

As a result of the test in June 1955, the conclusion was reached that a recharge well, as such, was impractical because the silt would clog the water-bearing formation. The next step, to learn more about inexpensive recharge, was to reclean the well and install per-

manent pumping equipment. This was done, and it is believed that it is highly significant that during redevelopment more formation sand was removed than during the initial development.

The next runoff to furnish sufficient water for a test did not come for another 2 years. During the last week in April 1957, the area received 5 in. of rain, and the lake filled with water. When recharging was started on Apr. 30, 1957, the well took water at the rate of 1,400 gpm, whereas in 1955 the initial rate had been only 1,050 gpm. After 23 hr of recharging, the input was 800 gpm, as compared to 540 gpm in 1955. At the end of 23 hr, the valve was closed and the well was pumped for 1 hr at the rate of 1,000 gpm. This cycle of 23 hr of recharging and 1 hr of pumping was continued without interruption for 30 days and nights, the lake being drained three times in succession. Although no analyses were made to determine the amount of the silt or clay entering the well during recharging or removed during pumping, it again seemed highly significant that the input rate at the end of 30 days was equal to the input rate at the start of the test. During the entire period of recharging, the average rate of input was 920 gpm, and in 30 days 38 mil gal, or approximately 116 acre-ft, was put in storage underground through this one well.

Sediment Problem

The amount of sediment that can be pumped from a recharge well in a short period is of great importance. In order to obtain additional information regarding this question, a test was made during October 1958 on a recharge well in Hockley County west of Lubbock. Engineers with the United States Department of Agriculture at Bushland, Tex., collected numerous samples throughout one recharging and pumping cycle. During the recharging period of 22 hr, the well took 582,000 gal of water, which included 5,340 lb of clay; during the 1-hr pumping period, the well produced 36,000 gal of water but only 410 lb of clay, indicating that only 7.7 per cent of the clay was removed. The important questions are whether the clay will stay in suspension and be removed when the well is used for irrigation or adhere to the sand grains and eventually clog the formation.

The movement of silt and clay through a water-bearing formation and the clarification of lake water prior to artificial recharge through wells were subjects of study by two graduate students at Texas Technological College during the summer of 1959. The projects were sponsored by the district and the reports of the work were submitted to the college in partial fulfillment of the requirements for the degree of Master of Science.

The first report shows that the fine-grained material does not filter out of the water and build a cake on the face of the well; instead, it moves on into the water-bearing formation. Several tests in which recharge with muddy water continued for 23 hr and the well was then pumped for 1 hr showed that only 10 per cent of the clay-sized particles were removed. Tests on one well over a 2-year period showed that the permeability of the water-bearing formation was reduced about 15 per cent.

The second report discusses the use of chemicals to flocculate the suspended solids in the water, which were tried on several playa lakes during the spring of 1959. A flocculant,* in the

* Separan AP30; a product of Dow Chemical Co., Midland, Mich.

form of an organic, non-toxic white powder mixed with agricultural gypsum in the ratio of 1:5 was applied from a crop-dusting airplane at the rate of 1 lb of flocculant per acre-foot. It was dispersed adequately by wave action, and initial flocculation of the sediments ranged from 40 to 90 per cent. The results of the flocculation lasted for several days, except in those lakes that received additional water in the form of irrigation "tailwater" or rainfall. Two lakes that contained water of very little hardness failed to respond favorably. The cost of chemical treatment including the flocculant, agricultural gypsum, mixing and dusting, was about $2 per acre-foot. The operations showed that much of the suspended material could be settled from the lake water at moderate cost.

Conclusion

The High Plains Water District has advocated the beneficial use of the playa-lake water that is now lost through evaporation. The individual farmer, where practicable, should prepare his soil in such a manner as to store the precipitation in the root zone of the plants to be produced and prevent the water from running off into the lakes. If the water cannot be effectively stored in the soil, it should be pumped from the lakes directly to the fields. If the water can be neither stored in the soil nor pumped to the fields, it should be stored underground in the water-bearing formation where it will be available for use when needed.

Numerous individual landowners have been using recharge wells for more than 10 years. A few wells have failed because of mechanical difficulties or siltation, but letters and oral reports from several operators indicate satisfactory results. An irrigation survey in the summer of 1959 showed 130 recharge wells in operation in the Texas High Plains.

Although a substantial quantity of ground water is still in storage beneath the High Plains, the supply is being depleted. The only local source of fresh water to supplement the ground water supply for future needs is the precipitation that collects in the myriad of playa lakes.

The people of the region recognize the importance of salvaging the lake water which is now lost through evaporation; but, rather than participate in a long, drawnout research program to solve the numerous problems known to exist, the district is encouraging the development of an operational program by local people with local funds to find a cheap and practical method of salvaging the lake water.

——Conservation in Nassau County—*W. Fred Welsch*——

A paper presented by W. Fred Welsch, Eng. Consultant, Albertson, N.Y.

Nassau County, N.Y., is located on Long Island, the largest island on the Atlantic Coast, and is entirely surrounded by tidal salt waters, the Atlantic Ocean on the south and Long Island Sound on the north.

The problem of the conservation of ground water resources and streams in Nassau County, N.Y., is becoming increasingly important. They are a rich heritage, and must be safeguarded and protected from contamination.

Within a comparatively short span of years, Nassau, second youngest county in New York, having an area of 275 sq mi and a population of 1,400,000, has undergone a complete change of character. Almost overnight, great farmlands have been converted into thriving communities of thousands of homes, busy shopping centers, churches, colleges, schools, public buildings, and industries. Light industry is replacing housing as the core of the county's economic development.

Problems of Growth

The problem of the conservation of Long Island's fresh-water streams was recognized by local governing bodies. In 1925, Robert Moses, then chairman of the Long Island State Park Commission, sensed their future importance, and something definite has been done to prevent pollution and contamination of the streams. Surface areas were obtained on the south shore in order at once to protect the streams and their boundaries and furnish park and recreation areas. Additional lands bordering on these streams, nearly to their source, were acquired from private owners by purchase and, in some cases, by exercise of the right of eminent domain. The acquistion of lands and surface easements protects them as a means of insuring the safety of the water source. The county, town, and municipalities have also improved streams by installing storm water drainage facilities.

In 1950 there were twenty public sewerage systems and treatment plants in Nassau County. They served nine villages, seven special districts and two county institutions. The remainder used cesspools and septic tanks, or allowed sewage to flow directly into tidal waters. Since that time, the county has been engaged in the construction, maintenance, operation, and planning of trunk line collection systems and activated-sludge treatment plants (separate systems, excluding storm water) with increasing population density to prevent the contamination of ground water by cesspools and industrial wastes. Water discharged from air-conditioning systems is not permitted to discharge into sanitary sewers.

As the wave of population mounted, more and more streets were paved; homes, schools, churches, colleges, commercial and industrial buildings were erected in great numbers; and sanitary sewers and storm drains were installed. The runoff of storm waters from pavements and roofs increased greatly, and instead of percolating into the ground, was carried away in vast quantities by storm sewers to tidewaters. The pumping levels of wells were decreasing. The need, therefore, was to devise a system of drainage that would restore rainfall to the soil and maintain the static levels of ground water.

Since 1932 Nassau County has been engaged in the investigation of ground water resources, and since the year 1936 in the investigation of surface water resources in cooperation with USGS and the Water Power and Control Commission.

Geology and Hydrology

Long Island is underlain by bedrock consisting mainly of schists and gneisses. The bedrock slopes gently approximately 64 ft/mi in a generally southeastern direction to depths of about 1,500 ft on the south shore and 2,000 ft at the eastern end of the island. The material between the rock

floor and the surface of the island consists of successive layers of sand and gravel aquifers interspersed with lenses of clay. These water-bearing formations have considerable magnitude and are hydraulically interconnected.

Water-bearing formations in Long Island are Upper Pleistocene glacial deposits, Jameco gravel, sands of the Magothy and Lloyd sand member. In Nassau County there are 50 public water supply systems serving villages, water districts, and private companies, all supplied from wells. During the period 1950–58, water consumption in the county has increased from 67.9 mgd to 136.1 mgd for domestic, industrial, air conditioning, and agricultural usage.

Salt Water Intrusion

Because of the widespread occurrence of highly productive water-bearing material and other favorable factors, the ground water resources of Long Island have been used extensively for many years for industrial, public-supply, and agricultural purposes. Overdevelopment in the heavily industrialized and populous areas at the western end of Long Island caused a gradual decline of water levels. In 1933 it was discovered that the water table was below sea level in an area of more than 40 sq mi in Brooklyn and that sea water was moving into the area. Subsequently all public water supply wells were abandoned in Brooklyn.

At sixteen outpost observation wells in proximity to the shore lines records are made of the fluctuation of static water levels and chloride content of the water to detect any movement of the salt water front. In addition, there are 300 water table observation wells on a grid system, eight surface water gaging stations, and a weather bureau observation station.

Control Regulations and Agencies

In 1933 the state legislature, recognizing the seriousness of the ground water situation, took steps to protect the public supplies on Long Island from further overdevelopment. A conservation law was passed placing the ground water resources of Long Island under the jurisdiction of the New York State Water Power and Control Commission. This conservation law, as amended, states that no well having a pump capacity in excess of 45 gpm shall be drilled unless approved by the commission. This provision does not apply to agricultural wells or fire wells with no permanent pumping equipment. All well drillers are required to be licensed on Long Island.

The commission also requires that ground water pumped for air conditioning, refrigeration, or air cooling be put back into the ground in an uncontaminated condition through diffusion wells or recharge basins.

Where public water supply wells have static levels above the ground surface near the shore, special devices are required to prevent waste to tidewater due to overflow when the wells are not in service.

Replenishment with Storm Water

In anticipation of continued population increase, the Nassau County Board of Supervisors, with foresight and vision, authorized, in 1936, the development of a long-range master drainage and water conservation program, which was prepared for the then existing Nassau County Sanitation Commission (now the Board of Supervisors), under the author's direction.

This plan provided for the construction of artificial storm water recharge and impounding basins 1 acre or more in size as a conservation measure to replenish ground water storage in areas where feasible. It was expected that this would save millions of gallons of rainwater which otherwise would be lost to tidal salt waters.

Recharge basins in Nassau County serve several purposes:

1. To replenish the ground water supply by returning to the ground the storm water runoff from rainfall, which otherwise would be carried off to streams and from there to tidal waters.
2. To provide drainage outlets without construction of long conduits to streams or tidewaters.
3. To reduce the size of conduits required for storm water drainage by impounding waters during peak flows.
4. To discharge waste water from air-conditioning systems and uncontaminated water used for industrial processing at industrial plants.

Large-diameter precast diffusion pipe of the DePasquale type with flared openings has been installed by the caisson method to drain small tributary areas, such as street intersections and shopping centers, and to augment seepage in several recharge basins.

Although the earlier recharge reservoirs, comprising more than half the total, were constructed as single basins, the later and approved design provides basins consisting of two units of approximately equal size. The first serves as a settling basin to remove the sediment which would otherwise prevent percolation into the ground. The second is a seepage or percolation basin. These two basins are separated by a dyke, and connected by conduits equipped with control gates. In some locations the seepage basin may be constructed at a lower level than the settling basin. Ramps are required for access to maintenance equipment.

The combined capacity of the two basins is made sufficient to impound the estimated runoff from the tributary watershed area caused by a 5-in. rainfall in 2 days or, in heavily built-up areas where there is danger of flood damage during abnormal storms, by an 8-in. rainfall in 2 days. County precipitation statistics indicate that a 5-in. rainfall in 2 days is likely to occur about once in 5 years. Because the settling or detention basin will silt up in 1–2 years, it cannot be depended on for recharge purposes, and percolation from the seepage basin cannot be counted on to reduce the storage required. The total capacity of the two basins is designed to store the total runoff. The average annual rainfall is about 42 in., with the usual monthly variations.

Experience has shown that the dependable seepage rate is 24 gpd/sq ft, or approximately 1 mgd/acre. Elaborate tests have continued since 1947 in cooperation with the USGS Surface Water Branch, on a small observation basin within the settling unit at the storm water recharge basin located at Rockaway Road in Garden City.

Estimation of runoff requires the choice of certain coefficients selected by judgment according to steepness of the ground and the condition of its surfaces and what they may be expected to be 30 years in the future. It is recognized that pervious areas on the land surface decrease due to construction of new buildings and pavements. In Nassau County, residential, industrial, and business development can be expected to increase the

percentage of such impervious areas, constantly decreasing the rainfall normally seeping into the ground.

Around each recharge basin, a permanent galvanized chain link fence with barbed-wire brackets, including gates and a concrete curb, is required. A number of the recharge basin sites have been landscaped and developed into park areas for recreational purposes and are an asset to the community.

Analyses of samples of water from several storm water recharge basins indicated that chlorides varied 2–4 ppm, iron 0.1–0.8 ppm, and dissolved solids 132–218 ppm. At one of the recharge basins the phenol concentration was 0.01 ppm. This is reduced to a negligible amount by dilution when the recharge water seeps into the ground water table below the bottom elevation of the recharge basins.

The phenols present probably originated from the storm water runoff from street pavements in the tributary watershed area which are surfaced with bituminous tar material. No phenol is present where there is asphaltic pavement.

The analysis shows that the chlorides and dissolved solids are within the requirements of the USPHS Drinking Water Standards.

As far as pathogenic bacteria are concerned, filtration through the subsurface sand would remove them. There has been no indication of bacteriologic or chemical contamination in any of the county's public water supply wells located in proximity to artificial-recharge basins. There are more than 600 wells in the 50 public water supply systems, and about 700 industrial wells.

All storm water drainage systems and recharge basins are required to be constructed in accordance with the specifications of the local municipal authority (if any) and the Nassau County Department of Public Works. All plans require approval by the Nassau County Planning Commission and the commissioner of public works.

Conclusion

In Nassau County, approximately 40 mgd, and, in neighboring Suffolk County, approximately 10 mgd, of runoff is estimated to be annually replenishing the ground water storage at the present time. Future development may ultimately increase these figures to 50 mgd in Suffolk County and 70 mgd in Nassau County.

Under the long-range drainage and conservation program, 438 recharge basins have been constructed, 369 are county-owned and maintained, 6 are county-maintained, but not owned, and 63 are privately owned. In Suffolk County, east of Nassau, more than 400 recharge basins are in use.

Current efforts to conserve ground water supplies include artificial recharge basins of 1 acre or more in size, large-diameter pipe storm water diffusion wells, diffusion wells for cooling and air-conditioning water, industrial waste treatment and water reuse, and enlightened study and control by governmental agencies.

Effects of Stimulation on Well Operating Costs and Its Performance on Old and New Wells

Louis Koenig

A contribution to the Journal by Louis Koenig, Research Consultant, San Antonio, Tex. This article is the third of a series by the author on various aspects of well stimulation. Earlier articles in this series were published in the March and May 1960 issues of the Journal.

IN previous articles [1, 2] the results of a nationwide survey of water well stimulation practice were analyzed to evaluate the technical performance of stimulation and the economic performance measured by investment costs. Although the original purpose of the investigation was to ascertain the potential reduction in investment cost for ground water supply, other ponderable economic advantages came to light during the study. It was decided, therefore, to investigate the savings in operating costs effected by stimulation treatment, as well as to determine whether the age of the well—that is, the length of time in service—has any appreciable effect on the technical and economic performance of stimulation. This article sets forth the criteria used in both these investigations and the conclusions reached.

Operating Costs

In the case history study, an Edwards limestone well producing 2,000 gpm with a 30-ft drawdown was scheduled to be acidized, and, as the water requirement was known to be less than 2,000 ppm, inquiry was made as to the justification for the treatment. The engineer in charge believed that by stimulation the drawdown could be reduced to 10 ft at the same production, thus saving 20 ft of pumping lift. The actual saving in electrical energy for pumping the same amount of water at the reduced lift amounted to a little more than $8.50 per day when computed from the rule-of-thumb figure of 1.5 cents per thousand gallons per hundred feet of lift. The cost of the treatment was approximately $2,500. Accordingly the owner could expect to recover the cost of the treatment in about 10 months of operation. It should be obvious that a return of this magnitude constitutes ample economic justification for the treatment.

Such potential savings in operating costs as a result of well stimulation are analyzed and evaluated quantitatively in what follows. This is accomplished by generalizing the figures over all the cases in the survey.

Payout Time

Payout time is defined as number of days of operation between the time of stimulation and the time that the cumulative savings in pumping energy costs at the same production rate equal

the cost of the stimulation treatment. It was assumed that all wells were powered with purchased electrical energy. It is known that in some areas of the country wells are operated with natural gas, gasoline, or diesel power, and that this energy is usually cheaper than electrical energy, but it was evident that to determine the energy source for each well and compute the cost factors for nonelectric-powered wells would have overtaxed the resources of the study. The present analysis, then, is based on an assumption that all the wells studied are electrically powered. Thus, the hypothetical model will be somewhat more favorable to stimulation than the actual situation, but the extent of the error will be small because the percentage of nonelectric-powered wells in the study is small.

Power computations. The pumping horsepower for the production before treatment for each producing well was computed on the basis of an average wire-to-water efficiency of 60 per cent and a discharge head of 20 psi. From the production rate before treatment and the specific capacity after treatment, the hypothetical drawdown after treatment was computed, which, when added to the static level, gave the hypothetical pumping level after treatment at the previous production rate. Hours of daily use for each well by use category were assumed to be: nonpotable industrial supply, 8; waterflood supply, 24; disposal, 24; injection, 24; brine production, 24; irrigation supply, 12; potable industrial supply, 8; municipal supply, 24; domestic supply, 8. Using these daily operating times and the power data, the energy (kilowatt-hours) used per month was computed.

Energy costs. The electric utility supplying each well was identified [3] and its energy rates were looked up in the National Electric Rate Book.[4] The type of service applicable under the monthly energy consumption categories was in all cases the commercial or general service, some with a demand charge and some without. It is recognized that if well pumping is incidental to some other energy-consuming operation—for example, part of an industrial plant—or if it is only one of a number of wells served by the same meter, then, in general, the energy rate will be lower than that computed by the above method. To the extent that this occurs, the results of the analysis of the hypothetical model will be weighted slightly in favor of stimulation. If the usefulness of the operating-cost criterion had been recognized when the survey check lists were first being sent out, a question on energy costs could have been included. There was no possibility of accomplishing this after the survey was underway, however, and it is therefore impossible to determine precisely what percentage of the wells was on individual meters. A sample study of 50 wells taken at random showed that 82 per cent of the wells were in the top open-end rate bracket and therefore would reap no benefit from being on a shared meter. Although no individual wells met the demand minimum for the large-use category, if the wells were part of a larger network itself in that category, the energy charge would be considerably less.

Payout time computation. As might be deduced from the fact that most of the wells in the survey were rather well into the top energy consumption bracket, a sample study confirmed that

in 94 per cent of the cases studied the consumption before treatment and the hypothetical consumption after treatment were in the same rate bracket. The saving in all instances without demand charges was computed by using the change in pumping level and the energy rate for the applicable bracket in the formula,

$$T = \frac{C_t \times 3.185 \times 10^5}{q_b \times \Delta L \times r \times u}$$

in which T is the payout time (calendar days), u is the period of daily use (hours), C_t is the cost of treatment (dollars), q_b is the production rate before treatment (gallons per minute), ΔL is the pumping level before minus the pumping level after (feet), and r is the incremental electric-energy rate for the consumption before treatment (cents per kilowatt-hour). When a demand charge was also made, this short-cut formula did not apply; the monthly costs before and after treatment were computed directly.

Payout Production

Another measure of payout is payout production, which is defined as the cumulative production at which the savings in power charges equal the cost of treatment, or

$$Q_p \times 10^6 = 60 T q_b u$$

in which Q_p is the payout production (in millions of gallons). This quantity is useful in comparing operating cost savings among wells of widely different production rates. In the simplified equation above, Q_p is a function only of treatment cost, energy rate, and saving in lift, for

$$Q_p = \frac{1.951 C_t}{\Delta L \times r}$$

Injection Wells

A modification of the above procedure was necessary for injection and disposal wells. For those wells for which data on static levels were available, it was possible to compute the negative drawdown (buildup) corresponding to the negative production (input). The procedure therefore was the same, except that the 20-psi discharge pressure was not added in computing kilowatt-hours per month. Data for some disposal or injection wells did not include a static level, but did include an injection rate and a well head pumping pressure. In this category were three subtypes for which no information on specific capacity was available. In the first type the injection rate after treatment is the same as or approximately the same as before treatment, but the well head pressure is different. For this subtype differences in well head pressures are converted to feet of head, the injection rate is converted to gallons per minute, and the already developed formulas then apply.

In the second subtype the well head pressure after treatment is negative or a vacuum, and the injection rate is higher after than before treatment. This corresponds to a zero head against a pump operated to produce an injection rate after treatment equal to that before treatment. The formulas developed therefore apply to this subtype also.

In the third subtype, well head pressures are available and there are several injection rates before or after or both. To obtain well head pressures before and after treatment at equal injection rates, the injection rates were plotted against well head pressures. From the resulting curves an injection

TABLE 1

Distribution of 346 Treatments in Payout Time Sample by Use, Aquifer Type, and Treatment

Use	Per Cent of Total Treatments	Aquifer Type	Per Cent of Total Treatments	Treatment	Per Cent of Total Treatments
Brine Production	2.9	Consolidated (undifferentiated)	7.2	Hydraulic fracturing	5.5
Disposal	4.1	Consolidated limestone	9.5	Pressure acidizing	23.4
Waterflood injection	2.9	Consolidated sandstone	37.9	Shooting	34.4
Waterflood source	.6	Unconsolidated	28.6	Surging	11.6
Industrial (nonpotable)	4.3	Unknown	16.7	Vibratory explosion	17.4
Irrigation	12.1			Unknown	7.8
Potable	63.6				
Unknown	9.5				
All types	100		100	All types	100

rate after treatment equal to the highest measured injection rate before treatment was selected. If this was not possible the "after" curve was extrapolated to the "before" injection rate. If there were only one measured value either after or before treatment, that value was used, the other being extrapolated. In this way well head pressures were selected corresponding to equal injection rates before and after treatment.

In the computation of payout times it is assumed that well performance is maintained. If the specific capacity declines after treatment, the computed payout times are too low.

Analysis Results

Application of the computation methods described above resulted in 346 treatments for which payout times could be calculated. The distribution of these by type of well, aquifer type, and stimulation type is given in Table 1.

Figure 1 shows the cumulative frequency distribution of payout times for all cases in the sample. The median is a little more than 3 years, which is a reasonably good but not spectacular return. It signifies that in the median the saving in pumping cost will pay out the cost of treatment in 3 years, savings after that time being pure gain.

TABLE 2

Payout Times and Productions for Various Categories of Treatments

Treatment Category	No. of Treatments	Median Payout Time (T) *days*	Treatments Superior to 10 per cent Compound Interest* %	Median Payout Production (O_p) *mil gal*
All treatments	346	1,150	75	232
Treatments in consolidated aquifers	189	1,345	73	245
Treatments in unconsolidated aquifers	99	606	84	264
Surging	40	1,161	71	518
Shooting	119	1,266	75	305
Vibratory explosion	60	416	95.5	157
Pressure acidizing	81	1,280	71	140
Hydraulic fracturing	19	2,070	61	97

* "Superior" means that the investment in stimulation produces a better rate of return than investment at 10 per cent compound interest.

For the best 10 per cent the payout time is less than 6 months, but for the worst 10 per cent it is almost 20 years.

If the cost of treatment were invested at 10 per cent compound interest it would "pay out"—that is, return an amount equal to itself—in 7.5 years. To use the money for well stimulation would be preferable to investing at 10 per cent per year in 75 per cent of the cases in this study.

The distribution curves for the various breakdown categories are quite similar to that in Fig. 1, all having long straight-line portions of approximately the same slope. A comparison of highlight points from such curves is shown in Table 2. Some characteristics of the sample are of importance in interpreting the table. The treatments in unconsolidated aquifers were performed almost entirely by surging and vibratory explosion. Thus the median for treatments in unconsolidated aquifers reflects the unusually low median for vibratory explosion. Practically all of the surging and vibratory-explosion treatments were made on wells in unconsoliated formations. A large number of the shooting treatments happened to be on wells in a sandstone formation. The hydraulic-fracturing results are exceptionally high because most of the wells treated by that method were injection wells. Injection rates are usually quite small compared to production rates. Therefore the potential savings in one day's operation are comparatively small, and, as the treatment costs are all of the same order, low-capacity wells necessarily have longer payout times.

This difference can be eliminated by comparing, rather than the payout times, the payout production—that is, the number of gallons of water pumped before the savings equal the cost of treatment. This quantity is given in the last column of Table 2. Whereas the order (ascending) in payout times is vibratory explosion, *all treatments*, surging, shooting, pressure acidizing, and fracturing, the order in payout production is fracturing, pressure acidizing, vibratory explosion, *all treatments*, shooting, and surging. It can be seen that the average for vibratory explosion treatments is superior

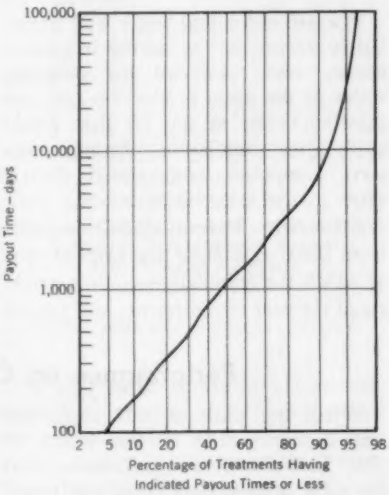


Fig. 1. Cumulative Frequency Distribution of Payout Times

The median payout time for the 346 treatments represented by the curve was 1,150 days, or a little more than 3 years.

to the average for all treatments by both criteria; the averages for surging and shooting treatments are inferior to the average for all treatments by both criteria; and fracturing and pressure acidizing are inferior by the time criterion but superior by the production criterion.

Nevertheless, the only criterion on which economic choice would be based

is that of payout time, and in this it is seen that more than 60 per cent of the treatments by any method show returns superior to an equivalent investment at 10 per cent compound interest. Similar computation shows that more than 80 per cent of any or all types of treatment give a better return than an equivalent investment at 6 per cent compound interest.

Summary

For 346 individual water well stimulation treatments the saving in cost of energy was computed for pumping water at the same production rate (or injection) rate at the lift that would apply after stimulation. Energy costs were computed from actual electric rates in the areas in which the wells are located. Payout times computed from these data show the elapsed time at which the cumulative savings would equal the cost of treatment; and payout production is the corresponding figure for the volume of water produced.

Median payout times are about 3 years in most categories, being lower for vibratory explosion and higher for hydraulic fracturing. This is because of the low production rate associated with the hydraulic-fracturing treatments (mostly injection wells). Median payout production for all treatments is about 230 mil gal, being as low as 97 mil gal for hydraulic fracturing and as high as 518 mil gal for surging.

In the best 10 per cent of the sample, the payout time is less than 6 months, and in 75 per cent of the sample stimulation is the economical choice over investment of the same amount of money at 10 per cent compound interest. In every category or type of treatment, more than 80 per cent of the treatments represent a return superior to investment at 6 per cent compound interest.

Performance on Old and New Wells

When the wells in this study are analyzed according to the length of time between their construction and the time of treatment, they are found to fall in two general categories, "new" and "old" wells. In the "new" category the drilling is completed, the well is tested and, within a few days, or a few weeks at most, it is treated and, finally, tested again. In the "old" category, the drilling is completed, the well is tested, placed in service, and operated for a period of time before it is again tested, treated, and, finally, tested again. The interval of operation varies in the cases studied from a few weeks to many years.

The essential difference between the two categories is that the old wells have seen a period of operation—that is, of producing water—prior to the time they are treated. The new wells are subject to underground flow resistances resulting from conditions in the aquifer itself and from any damage due to the drilling operation. Common in the latter is plugging with mud used in the drilling or compaction and movement of fines due to the percussion methods. The old wells may be subject to these types of underground resistances also, but they may have additional resistances that are built up as a result of the production of water. Typical resistances are those from chemical or biologic deposition in the formation or on the well screen, or from movement of fines by the water.

If representative samples are available and if their analysis shows considerable differences in performance between new and old wells, some tentative conclusions may be drawn. For illustration, if the old wells show improvements considerably greater than the new wells, one might conclude that the treatment methods used are successful in removing chemical or biological deposits and fines, but not so successful in altering aquifer properties or removing resistances due to drilling damage.

All other terms and methods of analysis used are the same as those described in the previous two articles of this series.[1, 2]

Characteristics of Sample

In analyzing the data presented below it should be noted that the same reservations as to the nature of the sample, the approximate nature of specific capacity as a measure of performance, and other factors mentioned in the first article of this series[1] apply here as well.

In some of the tables below blanks appear. Some of these blanks represent data which are inconclusive because the number in the sample for that category is too small; others represent an invalidity of another type.

TABLE 3

Improvement Ratios (A/B) *and Failures in Old, New, and All Wells*

Well Classification	No. of Treatments	*A/B* Ratio		Failures *per cent*
		Median	Median for Best 10 per cent	
Old	238	1.77	5.9	13
New	91	2.73	—	9
All	455	1.97	11.9	11

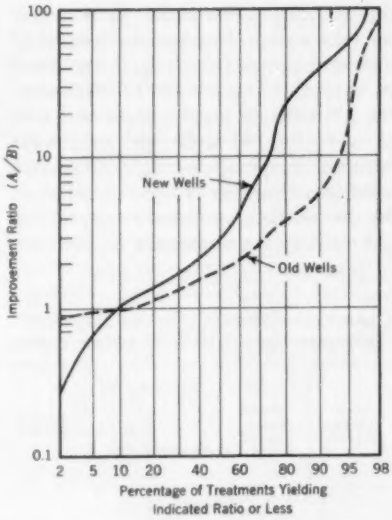


Fig. 2. Cumulative Frequency Distribution of Improvement Ratios (A/B Criterion) for Old and New Wells

Further data are given in Table 3.

In a later paper it will be shown that there is a trend to higher A/B ratios and, presumably, A/O ratios at the lower ranges of permeation factor. The character of the sample for new and old wells is such that in some categories a large part of the new-well sample is concentrated in the lower permeation factor ranges. This means that a routine analysis of the data would ascribe high performance in certain categories to the newness of the well, whereas it is more likely to result from the low permeation factor.

Overall Analysis

Figure 2 shows the frequency distribution of improvement ratios (A/B) for old wells and new wells. As can be seen from the general position of

the curves, performance is superior for new wells. Some of the numerical highlight points from Fig. 2 are listed in Table 3. The number of treatments for all wells is greater than the sum of cases for old wells and new wells because it could not be determined whether certain wells were old or new. In the median, new wells outperform old wells by approximately 54 per cent.

TABLE 4

Improvement Ratios (A/B) *and Failures in Old, New, and All Wells by Aquifer Type*

Well Classification	No. of Treatments	*A/B* Ratio		Failure *per cent*
		Median	Avg for Best 10 per cent	
Consolidated				
Old	127	2.10	9.6	8.0
New	82	2.80	41.5	8.5
All	259	2.41	25.0	7.0
Unconsolidated				
Old	103	1.33	3.9	24
New	4	(1.59)	(3.78)	(40)
All	130	1.45	3.85	20

The percentage of failures for new wells is somewhat less. Based on these data one might expect to obtain somewhat greater improvement for new wells than for old wells (173 per cent against 77 per cent in the median). Also failures for new wells would be about one in eleven compared with about one in eight for old wells. The sign of the differences is such as to lend support to the hypothesis that flow resistances resulting from operation are more difficult to remove than flow resistances from drilling or the nature of the aquifer itself. The magnitude of the differences, however, does not seem sufficient to make this support a very strong one.

Analysis by Aquifer Type

Improvement ratios for old and new wells are broken down between consolidated formations and unconsolidated formations in Table 4. There were only four treatments on new wells in unconsolidated aquifers. A similar trend is shown. The medians

TABLE 5

Improvement Ratios (A/B) *and Failures in Old, New, and All Wells, by Treatment*

Well Classification	No. of Treatments	*A/B* Ratio		Failures *per cent*
		Median	Avg for Best 10 per cent	
Surging				
Old	70	1.18	3.0	27
New	4	(1.43)	(2.2)	(20)
All	79	1.20	3.4	24
Vibratory Explosion				
Old	34	1.95	5.6	0
New	2	—	—	—
All	51	2.25	7.6	0
Shooting				
Old	80	2.20	5.8	3
New	27	2.45	100	7
All	120	2.12	8.2	5
Pressure Acidizing				
Old	42	1.79	13.7	19
New	28	2.40	10.8	11
All	133	2.61	16.1	13
Fracturing				
Old	10	2.30	—	13
New	24	—	—	11
All	40	5.00	—	13

for new wells are higher than the medians for old wells. In the unconsolidated formations, there is little difference in the best 10 per cent. The percentage of failures is about the same in both types of aquifers. One would conclude that the chance for failure is about the same with new wells as with old wells in both types of formations; that the median improvements will be slightly greater for new wells in both categories; and that in unconsolidated formations there is little difference in the best 10 per cent. Conclusions concerning the sign and magnitude of the differences are the same as those in the preceding section.

Analysis by Treatment Type

In Table 5 improvement ratios for old and new wells are broken down by type of treatment. The differences in magnitude and size for surging, shooting, and vibratory explosion follow the pattern for the previous two categories. Thus it may be concluded that performance in new wells is slightly superior to performance in old wells. In shooting, in contrast to the other categories, failures in new wells are somewhat greater than those in old wells.

In pressure acidizing, however, performance in new wells is again slightly better than in the old, except in the best 10 per cent in which performance in old wells is slightly—but probably not significantly—superior.

In Table 6 the relative performance of treatment on old and new wells is evaluated in numerical terms. Measured by the median there is seen to be a modest but consistent superiority for new wells over old.

Chance of Specific Improvement

Another method of comparing the performance is to measure the chance of obtaining specified improvements. In Table 7 are shown the chances of doubling the specific capacity before treatment. In addition to giving a rough measure of the potentialities of stimulation and the relative performance of the various techniques, the data in the table support the earlier conclusion that stimulation performance in new wells is somewhat superior to performance in old wells, in that there is a greater chance of doubling the specific capacity of new wells. In the chances for failure there are small differences, in that either new wells or old wells may be somewhat superior, depending on the treatment method.

TABLE 6

Relative Stimulation Performance Criteria for New and Old Wells

Treatment Category	Ratio of A/B Ratios for New Wells to Those for Old Wells	
	Medians	Best 10 per cent
All treatments	1.54	
Treatments in consolidated aquifers	1.33	
Treatments in unconsolidated aquifers	1.20	1.00*
Surging	1.21	1.00*
Shooting	1.11	
Vibratory Explosion		
Pressure Acidizing	1.34	0.79
Fracturing		

* Approximate.

Table 8 contains similar figures relating to the chance of improving the specific capacity of the well to equal that of the original well when constructed. Shown are the percentages of failures to reach the specific capacity of the original well, and the percentages of treatments producing twice the specific capacity of the original well. In general, compared to old wells, new wells have about four times the chance

TABLE 7

Chance of Achieving Specified A/B *Improvement Ratios*

Treatment Category	Chance of Twofold Improvement ($A/B \geq 2.0$) *per cent*			Chance of Failure ($A/B \leq 1.0$) *per cent*		
	Old Wells	All Wells	New Wells	Old Wells	All Wells	New Wells
All treatments	42	48.8	64	14	11.2	9
Consolidated	55	59.8	70	7.5	7.3	8.5
Unconsolidated	25	27.7	44	24	17.7	40
Surging	14	16.4	13	30	24.1	21
Shooting	60	54.2	55	2.5	5.0	7.5
Vibratory explosion	49	55.3	—	0	0	—
Pressure acidizing	43	59.4	68	19	12.8	11
Fracturing	60	72.5	87.5	11	12.5	11

of doubling the original production, and only one-tenth the chance of failure.

The contrast between new and old wells is much sharper for the A/O criterion than for the A/B. But there is a significant difference between A/O failures for new wells and for old wells. In a new well an A/O failure means that the well was actually damaged by the treatment, causing a decrease in the specific gravity. In an old well, however, this is not necessarily so, as an old well which has declined may be improved by treatment without actually reaching the original specific capacity. For example, if an old well has declined to 10 per cent of its original production, then it would require an A/B ratio of 10 to bring it back to the original specific capacity. There is, however, only about a 6 per cent chance that a 10-fold increase in the A/B ratio will be obtained in an old well. This means that there is only a 6 per cent chance that an old well having declined to 10 per cent of its original specific capacity will be brought back to the original specific capacity by treatment. Actually, 38 per cent of the old wells in the study were brought back to the original spe-

TABLE 8

Chance of Achieving Specified A/O *Improvement Ratios*

Treatment Category	Chance of Failure ($A/O \leq 1.0$) *per cent*			Chance of Twofold Improvement ($A/O \geq 2.0$) *per cent*		
	Old Wells	All Wells	New Wells	Old Wells	All Wells	New Wells
All treatments	62	43	6	16	36	76
Treatments in consolidated aquifers	42	21	3	27	53	76
Treatments in unconsolidated aquifers	81	79	—	5.3	6	—
Surging	81	75	—	7.5	12	—
Shooting	54	32	0	13.5	30.5	61
Vibratory explosion	58	61.5	—	1	7.7	—
Pressure acidizing	52	28.6	6	22	49	81
Fracturing	20	6.5	8	40	80.7	86

cific capacity or better. The B/O ratio for the 133 old wells in the study for which such data are available averaged 0.46, indicating that on the average, wells were allowed to decline to approximately 46 per cent before stimulation. This average is slightly too high because it includes old wells which were stimulated more than once and which in some cases may have had B/O ratios greater than 1.0.

Performance on Successive Stimulation

The data allow some analysis of the performance on successive stimulations. In Fig. 3 the B/O ratio is plotted against the A/B ratios for first, second, and third stimulations. The five treatment types as well as the two aquifer types are distributed quite uniformly in the first and second stimulations, but the curve for the third stimulation, consisting of only six points, comprises only surging and pressure acidizing. It therefore cannot be given great weight, but the points do follow the pattern of the first- and second-stimulation curves. The trend of the solid lines, which represent approximately the medians at each B/O ratio, shows that as the B/O ratio decreases the A/B improvement ratio to be expected increases. It does not, however, increase sufficiently to bring the improvement ratio up to the dashed 45-deg line, which represents an A/O ratio of 1.0—that is, production of a specific capacity equal to that of the original well. As can be seen, the chances for bringing the performance of an old well up to the original performance become greater as the capacity before treatment approaches the original capacity. The chance of exceeding the original specific capacity when the B/O ratio has fallen to the region of 0.6–0.9 is 0.5. The position of the A/B median curve for the third stimulation is almost identical with that of the first stimulation, whereas that for the second stimulation falls somewhat below these at low B/O ratios and above them at high. The median A/B ratio for all instances of first, second, and third stimulation (which includes some treatments not on the graphs) are 1.74, 1.88, and 1.52 respectively. The differences among

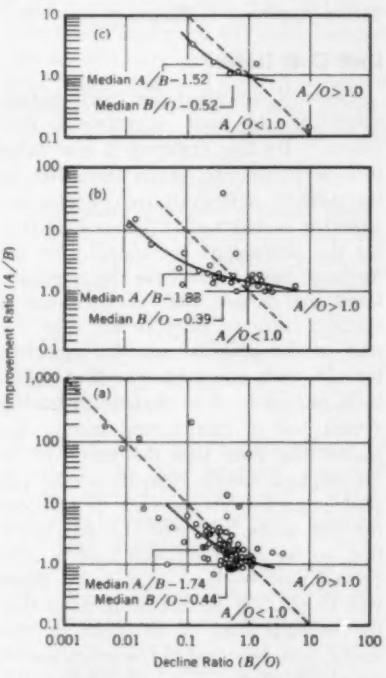


Fig. 3. Performance of Successive Stimulations of Old Wells

Parts a, b, *and* c *represent data for first, second, and third stimulations, respectively. There were 96 first, 29 second, and 6 third stimulations. The curves approximate the median* A/B *ratios at each* B/O *ratio. Second and third stimulations may include wells that were new on their first stimulation.*

these are of no significance. From the above it may be concluded that the study shows no significant differences among first, second, and third stimulations.

The median B/O ratios for all cases in which this ratio was available are shown at 0.44, 0.39, and 0.52 for the three stimulations respectively. This indicates that median practice is to allow a well to decline to 40–50 per cent of its original specific capacity before applying stimulation.

Unit Cost Ratios

Table 9 describes the performance according to unit investment cost ratios.[2] By this criterion a low value is a desirable one. It is seen that, in the median, new wells are considerably superior to old wells; this is also true for the percentage of failures. In the median, new wells have been stimulated for a unit cost of incremental specific capacity only 6 per cent the cost of the original specific capacity; for old wells the corresponding figure is 56 per cent. The chances of having a unit cost of incremental specific capacity less than half the unit cost of the original specific capacity are 88 per cent for new wells and only 47 per cent for old wells. It may be concluded that so far as investment cost is concerned new wells are decidedly superior to old. It should be recalled that the original cost of all wells in this study, both new and old, was computed on a uniform basis of early 1959 costs.

In making these analyses an error was discovered in some of the data in the previous article on economic performance.[2] The error occurred in Fig. 2 of that article and in the discussion of that figure. Certain of the curves should be shifted to the left—that is, to a more unfavorable position. None of the conclusions are changed, but the data on median unit cost ratios should read: all methods, 0.32; surging, 0.82; shooting, 0.38; pressure acidizing, 0.13; hydraulic fracturing, 0.0017; vibratory explosion, 0.20. Failures were: all methods, 22 per cent; surging, 37 per cent; pressure acidizing, 0.8 per cent. The most unfavorable instance is not shooting, with a median of 0.38, but surging, with a median of 0.82, and this change makes the order of increasing value follow precisely the same pattern as did the order for the technical performance criteria.[1] The median cost of improvement of all methods but surging occurs at a unit cost less than half the original.

TABLE 9

Stimulation Performance in Old, New, and All Wells According to Unit Investment Cost Ratios

Well Classification	No. of Treatments	Median Ratio	Chance of <0.50 ratio *per cent*	Chance of Failure (>1.0 ratio) *per cent*
Old	126	0.56	47	31
New*	35	0.063	88	2
All	185	0.32	60	22

* Excluded from the tabulation for new wells are 18 cases of fracturing which will be shown in a later paper to have high performance associated with a very low permeation factor. The median if these wells are included is 0.013 instead of 0.063.

In Table 10 is shown the stimulation performance on old and new wells according to payout times (Fig. 1). There are no significant differences among old wells, all wells, and new wells.

Summary

The analyses of the previous articles have been applied to the sample broken down into two categories—"new" wells treated just after construction

and "old" wells that have been in operation for a period prior to treatment. For the A/B criterion, the median A/B ratio for new wells is 2.73 compared to 1.77 for old, or a ratio of new to old of 1.54. This ratio of new to old is relatively the same for consolidated and unconsolidated aquifers and for all types of treatment but fracturing, for which no conclusions can be drawn. The chance of doubling the specific capacity by stimulation is 1.5 times as great for new wells as for old, and the chance of failure is only two-thirds as great.

By the A/O criterion, the chance of reaching twice the original capacity with a new well is four times as great as with an old, and the chance of failure is only one-tenth as great. This is to be expected because most old wells have declined from the original specific capacity in order to reach the capacity before stimulation. The median old well in the survey had declined to 45 per cent of its original capacity before stimulation for the first time, and to approximately the same extent before the second and third stimulations. There is no appreciable difference in the stimulation performance in old wells on first, second, and third stimulations. The more the well has declined before stimulation from its original specific capacity, the greater is the A/B improvement ratio achieved on stimulation, but the less is the chance of reaching the original specific capacity.

By the unit cost ratio criterion, the median for new wells is only one-tenth the median for old wells, and the chances for failure are only one-sixteenth that of the old. For new wells the chances of unit cost ratio less than 0.5 are almost twice as great as for old wells.

By the operating cost criterion, measured by payout times, there are no appreciable differences between new and old wells.

Conclusions

In practically every category stimulation performance on new wells is superior to that on old by almost every criterion. By the major criterion, the A/B ratio, however, the superiority is not very marked.

As is to be expected the A/O ratio is markedly lower for old wells because they usually have declined considerably from the original capacity before stimulation. The more a well has declined the greater the improvement on stimulation, but the less the chance of returning to the original capacity. There is very little difference in stimulation performance on first, second, and third stimulations.

TABLE 10

Stimulation Performance by Payout Times

Well Classification	No. of Treatments	Median Operating Time *1,000 hr*	Payout Time for Best 10 per cent *1,000 hr*
Old	195	23.5	4.1
New	60	23.9	6.2
All	346	21.9	3.5

By the unit cost ratio criterion, new wells are considerably superior to old, but medians for both are still considerably less than unity. By the operating cost criterion there is no difference.

The general conclusion to be drawn is that water well stimulation is a successful means of reducing lifting cost and that money spent on well treatment shows a comparatively high rate of return in reduced operating costs.

In this article, together with the previous two articles,[1, 2] it has been dem-

onstrated that water well stimulation is a technically and economically feasible practice applicable to a wide variety of wells and aquifers. By means of stimulation, additional production can be obtained from existing facilities, the investment cost per unit production can be reduced, and the energy cost for lifting can likewise be reduced. These conclusions apply, regardless of whether the well is new or old or has been stimulated before.

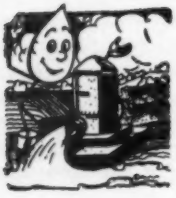
On the basis of these results it is recommended that serious consideration be given to the possibilities of well stimulation in each case before a new well is constructed, before a proposed well field is abandoned as uneconomical, before a newly constructed well is abandoned as being too low in production, and before an unsatisfactory old well is abandoned or subjected to drastic reconstruction. Water well stimulation should also be carefully evaluated for existing well fields where there may be a possibility of advantageously producing the desired total production more efficiently from a smaller number of wells, thus achieving lower capital investment and maintenance costs.

Acknowledgments

The financial and professional support of the Halliburton Co. for the entire study is gratefully acknowledged. Thanks are also due to the numerous well owners and others concerned with the field of ground water who have supplied data for the case histories. Special thanks are rendered to Lee McDougall who performed the very tedious and detailed computations and analyses.

References

1. Koenig, Louis. Survey and Analysis of Water Well Stimulation Practice. *Jour. AWWA*, 52:333 (Mar. 1960).
2. Koenig, Louis. Economic Aspects of Water Well Stimulation. *Jour. AWWA*, 52:631 (May 1960).
3. Ackerman, E. & Lof, G. *Technology in American Water Development.* Johns Hopkins Press (1959).
4. *National Electric Rate Book.* Federal Power Commission, Washington, D.C. (1960).



Status of Fluoridation in the United States and Canada, 1959

Task Group Report

A report of Task Group 2620 P—Fluoridation Materials and Methods, submitted by F. J. Maier (Chairman), San. Eng. Director, Div. of Dental Public Health, USPHS, Washington, D.C. Other members of the task group are R. L. Derby, H. A. Faber, A. E. Griffin, L. E. Harper, W. L. Harris, O. J. Muegge, R. W. Ockershausen, R. S. Phillips, R. C. Pickard, F. S. Taylor, H. W. Tracy, D. B. Williams, and J. C. Zufelt.

AT the end of 1959, 118,000,000 persons in the United States were served by public water supplies. Approximately 36 per cent of these, or 43,000,000 people, were using water containing at least 0.7 ppm fluoride. Of these 43,000,000 people, 36,000,000 were served water containing controlled and optimum amounts of fluoride, whereas the remaining 7,000,000 used water with naturally occurring fluoride in concentrations of 0.7 ppm or more (Table 1 and Fig. 1). The 0.7-ppm level is used as representing the lowest optimum fluoride concentration for use in areas of the United States where the mean maximum temperatures are the highest.

During 1959 the gain in the number of people using fluoridated water in the United States and Canada was 931,021, which, although substantial, is the smallest experienced since 1951 (Fig. 1). Four communities elected to discontinue fluoridation during the year, and none resumed it after having discontinued it. Since 1950, 100 communities have discontinued fluoridation, thirteen of them having reinstituted it after a temporary discontinuation (Table 2). This trend occurred in spite of the increasing number of reports on the effectiveness and overwhelming economy of fluoridation. During the 15 years since the first fluoridation installation began operation, no confirmed instances of objectionable mottled enamel have been observed, nor has anyone reported any experience of corrosion, caused by fluoridated water, of distribution mains or appurtenances.

In Canada, 22 new water suppliers, serving 125,000 people, started fluoridation during 1959 (Table 1). This is nearly twice the number of persons for whom fluoridation was started in 1957 and in 1958.

The majority of the 81 communities that adopted fluoridation during 1959 were small cities and towns. Nevertheless, because 93 per cent of all communities have a population of less than 10,000, a very large number of small communities have not as yet adopted fluoridation. For instance, only 4.5 per cent of the communities with less than 1,000 population are served by fluoridated supplies. On the other hand, more than 35 per cent of all cities of a population greater than 10,000 have adopted fluoridation (Tables 3 and 4 and Fig. 2).

TABLE 1

Growth of Fluoridation in the United States and Canada, 1945–59

Year	United States			Canada	
	Number of Communities Served	Number of Systems Using Fluoridation	Population Served	Number of Systems Using Fluoridation	Population Served
1945	6	3	231,920	1	51,100
1946	12	8	332,467	1	51,100
1947	16	11	458,748	1	51,100
1948	26	13	581,683	1	51,100
1949	49	29	1,062,779	1	51,100
1950	100	62	1,578,578	1	51,100
1951	344	171	5,020,502	1	51,100
1952	722	353	13,644,677	6	161,400
1953	970	482	17,200,031	8	213,350
1954	1,151	572	21,597,065	9	224,350
1955	1,304	668	25,224,031	19	806,730
1956	1,526	764	31,979,966	25	952,480
1957	1,643	873	33,822,952	33	1,018,330
1958	1,801	975	35,392,167	41	1,075,685
1959	1,878	1,048	36,199,047	63	1,199,826

TABLE 2

US Fluoridation Installations Instituted, Discontinued, and Reinstated, 1945–59

Year	Instituted*		Discontinued†		Reinstituted	
	No. of Systems	Population Served	No. of Systems	Population Served	No. of Systems	Population Served
1945	3	231,920				
1946	5	100,547				
1947	3	126,281				
1948	2	122,935				
1949	16	481,096				
1950	34	532,349	1	16,550		
1951	110	3,454,824	1	12,900		
1952	187	8,796,847	5	172,672		
1953	134	3,440,504	7	51,616	2	166,466
1954	108	5,462,975	20	1,069,875	2	3,934
1955	112	4,007,034	18	394,040	2	13,972
1956	105	6,905,648	13	188,082	4	38,369
1957	110	1,968,866	4	192,220	3	66,340
1958	104	1,584,345	2	15,130		
1959	76	957,192	3	150,312		
Totals	1,109	38,173,363	74	2,263,397	13	289,081

* Total, whether or not discontinued.
† Total, whether or not reinstated.

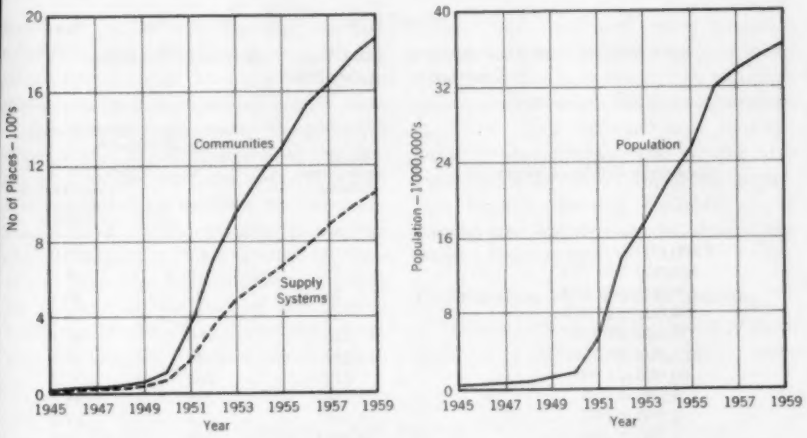


Fig. 1. Number of People, Communities and Supply Systems in the United States Using Fluoridated Water, 1945–59

By the end of 1959, approximately 36,000,000 people were served water containing optimum controlled amounts of fluoride. Fluoridated water was supplied by 1,048 systems.

Fluoridation Chemicals

Sodium silicofluoride continues to be the most popular chemical, being used by supplies serving more than 21,000,000 people. Sodium fluoride continues to be the chemical of choice for the smallest places. Fluosilicic acid is second most widely used, although it is being used by only 102 systems out of a total of 1,048 water supply systems. This is because of the large populations served by the Philadelphia, Chicago, and Baltimore systems, which use it. Calcium fluoride continues to be used satisfactorily and with considerable economy over other compounds by two water systems (Table 5). One additional community started using ammonium silicofluoride during 1959. Trends in

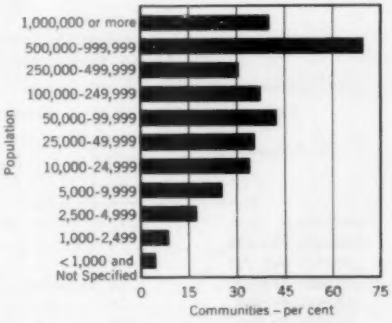


Fig. 2. Percentage of United States Communities Using Fluoridation, by Population, Dec. 31, 1959

More than 35 per cent of all United States cities of a population greater than 10,000 had adopted fluoridation by the end of 1956.

TABLE 3

*Distribution by Population Range of United States Communities Practicing Fluoridation, Dec. 31, 1959**

Community Population Range	No. of Communities in Range	Communities Using Controlled Fluoridation	
		Number	Percentage of Communities in Range
1,000,000 or more	5	2	40.0
500,000–999,999	13	9	69.2
250,000–499,999	23	7	30.4
100,000–249,999	65	24	36.9
50,000–99,999	126	53	42.1
25,000–49,999	252	89	35.3
10,000–24,999	778	262	33.7
5,000–9,999	1,176	296	25.2
2,500–4,999	1,846	318	17.2
1,000–2,499	4,296†	368	8.6
<1,000 or not specified	9,968†	451	4.5
All ranges	18,548	1,878	10.1

* Data drawn from USPHS and Bureau of Census sources.
† Places with fewer than 2,500 in urban territory are distributed in proportion to the distribution in rural territory.

TABLE 4

Distribution of Fluoridated Supplies by Ownership, Size of Community, and Agency Authorizing Fluoridation, Dec. 31, 1959

Population Range	Ownership				Authorization			
	Number of Communities	Public	Private	Other and Not Specified	Governing Body Alone	Referendum	Utilities Commission	Other and Not Specified
1,000,000 or more	2	2			2			
500,000–999,999	9	9			8	1		
250,000–499,999	7	6	1		7			
100,000–249,999	24	21	3		20	2		2
50,000–99,999	53	46	6	1	45	5		3
25,000–49,999	89	78	10	1	78	3	2	6
10,000–24,999	261	224	28	9	216	22	6	17
5,000–9,999	296	247	45	4	248	19	7	22
2,500–4,999	318	264	44	10	267	15	6	30
1,000–2,499	368	313	47	8	314	16	10	28
>1,000	231	176	55		204	11	5	11
Not specified	220	183	30	7	156	18	28	18
Total	1,878	1,569	269	40	1,565	112	64	137

the use of sodium fluoride, sodium silicofluoride, and fluosilicic acid are illustrated in Fig. 3. Additional data are given in Tables 6 and 7.

All compounds were in plentiful supply and no difficulty was experienced (unlike previous years) in obtaining fluosilicic acid in the amounts required. Even though some purveyors claim that unlimited amounts of fluosilicic acid can be furnished, it might be prudent on the part of prospective users to assure themselves that there will be reliable future sources before investing in solution feeding equipment. Consideration should also be given, in calculating the relative economy of using dry or liquid chemicals, to the cost of shipping a fluoride compound containing at least 75 per cent water.

A subcommittee of this Task Group working on fluoride feeding problems has devised a "feedability index," which was described in a previous report.[1] It was decided that this index was too difficult to use by the ordinary water utility with limited laboratory facilities. It is believed now that the particle size distribution of the dry compounds is one of the most important factors affecting feedability, and efforts are continuing to define the limits of these sizes.

Fluoridation and Dental Health

During 1950 the last examinations of children at Grand Rapids, Mich., were completed, 15 years after fluoridation started. The results (Fig. 4) showed the almost exact parallel with experience obtained in 1945 at Aurora, Ill., a community with natural fluorides near the optimum level.

A preliminary study, financed by the National Institutes of Health, on the cause of fluoride removal by home water softeners was completed by

TABLE 5

Chemicals Used in Communities With Fluoridated Water, by Population Range, Dec. 31, 1959

Population Range	Number of Systems	Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid Solution	Ammonium Fluosilicate Solution	Calcium Fluoride Solution	Other, Adjusted Natural Fluoride, and Not Specified
		Dry Feed	Soln. Feed	Dry Feed	Soln. Feed				
1,000,000 or more	5			2		3			
500,000–999,999	9			8		1			
250,000–499,999	13	2		10	1				
100,000–249,999	33	6	1	21		3			2
50,000–99,999	42	5		30	1	5			1
25,000–49,999	71	13	1	48	2	2	1		4
10,000–24,999	220	22	21	147	8	10			12
5,000–9,999	208	29	38	114	2	19	1		5
2,500–4,999	189	14	50	84	3	22	4	2	10
1,000–2,499	183	10	95	40	5	29			4
<1,000	64	1	49	2	4	8			
Not specified	11	1		1					9
Totals	1,048	103	255	507	26	102	6	2	47

TABLE 6

Use by Water Systems of Various Fluorine Compounds, 1945–59

Year	Total Systems	Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid Solution	Ammonium Fluosilicate Solution	Calcium Fluoride Solution	Other, Adjusted Natural Fluoride and Not Specified
		Dry Feed	Soln. Feed	Dry Feed	Soln. Feed				
1945	3	2	1						
1946	8	4	3	1					
1947	11	5	4	2					
1948	13	5	5	2		1			
1949	29	9	10	8		1			1
1950	62	12	21	24		3			2
1951	171	29	43	78		18	1		2
1952	353	50	86	177	3	33	2		2
1953	482	60	121	247	7	39	3		5
1954	572	68	136	300	7	48	5		8
1955	668	81	163	336	13	57	5	1	12
1956	764	92	185	376	15	63	5	1	27
1957	873	99	217	422	17	72	5	1	40
1958	975	102	238	475	24	88	5	2	41
1959	1,048	103	255	507	26	102	6	2	47

TABLE 7

Annual Cumulative Population Served Fluoridated Water, by Chemical Used, 1945–59

Year	Total Population Served	Sodium Fluoride	Sodium Silicofluoride	Fluosilicic Acid	Ammonium Fluosilicate	Calcium Fluoride	Other, Adjusted Natural Fluoride, and Not Specified
		Population Served Water Treated With Indicated Compound					
1945	231,920	231,920					
1946	332,467	315,747	16,720				
1947	458,748	428,028	30,720				
1948	581,683	430,963	30,720	120,000			
1949	1,062,779	840,225	96,274	120,000			6,280
1950	1,578,578	990,764	376,211	200,774			10,829
1951	5,020,502	1,386,453	3,316,999	302,109	4,112		10,829
1952	13,644,677	2,535,332	9,350,957	1,740,447	7,112		10,829
1953	17,200,031	3,007,445	12,181,735	1,815,939	9,612		185,300
1954	21,597,065	2,758,999	14,489,616	4,038,105	59,621		250,724
1955	25,224,031	3,528,671	16,374,030	4,980,228	59,621	2,700	278,781
1956	31,979,966	3,689,155	18,243,727	9,574,672	59,621	2,700	410,091
1957	33,822,952	4,004,493	19,399,638	9,633,259	59,621	2,700	723,241
1958	35,392,167	4,091,293	20,703,805	9,797,838	59,621	5,369	734,241
1959	36,199,047	4,131,878	21,362,189	9,838,025	67,121	5,369	794,465

R. L. Morris, of Iowa State University. It appears that the iron removed by the softening media constitutes an effective, although inefficient, fluoride removal mechanism. Additional work on the cure for this, as well as on the cause of fluoride increases observed in the water from some of the home softeners, is being continued.

A census of community water sources which contain natural fluoride was made by all the state dental directors and published by USPHS during 1959.[2] The data furnish reference material for those interested in detailed information about drinking-water sources in each state as well as in specific communities.

The water supplies of five consolidated schools in various parts of the country are being fluoridated at different levels to determine if it is possible to catch up on caries protection when the children's first 6 years of life have been spent in a practically fluoride-free area. The first dental

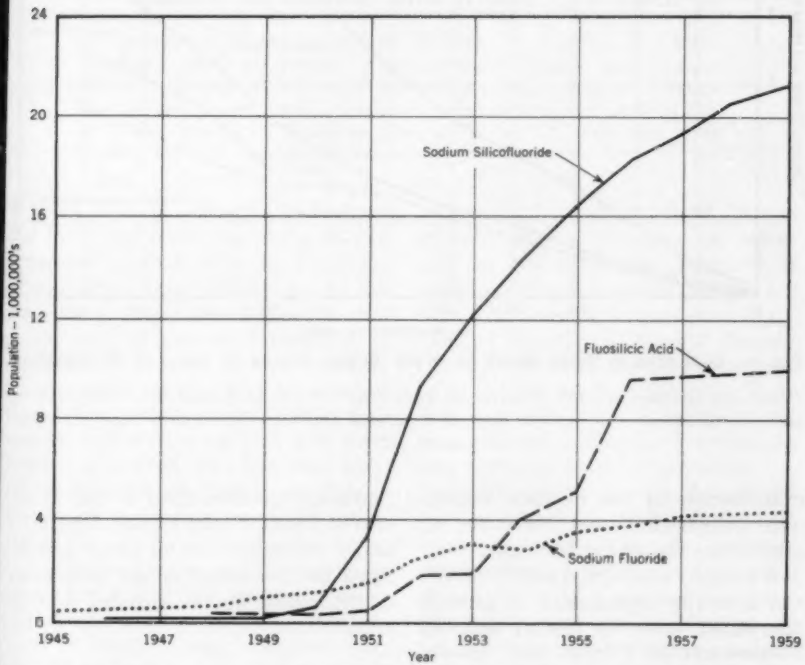


Fig. 3. Annual Cumulative United States Populations Served Fluoridated Water, by Chemical Used, 1945–59

Calcium fluoride is used by only two systems and ammonium fluosilicate is used by only six systems.

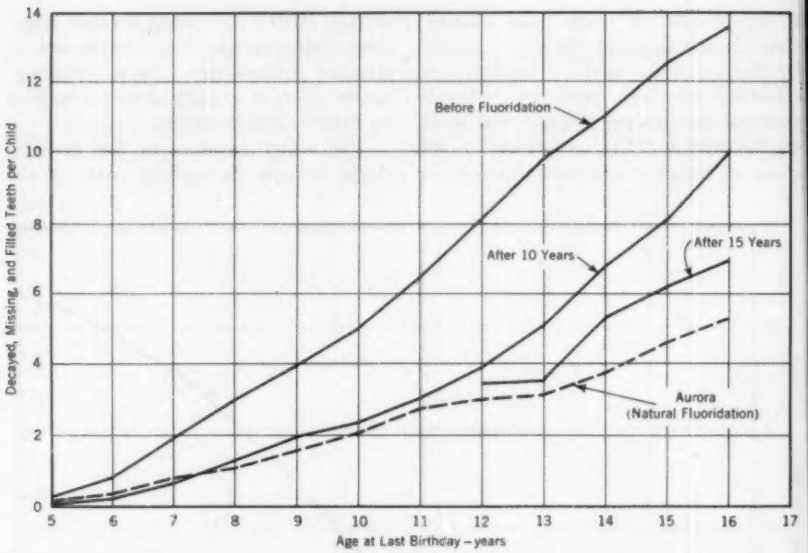


Fig. 4. Reduction in Tooth Decay in Grand Rapids During 15 Years of Fluoridation

There is a striking parallel between the experience of Grand Rapids after fluoridation and that of Aurora, Ill., where there is a natural fluoride content very near the optimum level.

examinations at one of these schools were completed during 1959, but no conclusions can as yet be drawn.

A contract was signed with USPHS and a service organization to provide fluoridated water to several hundred homeowners in Illinois with private water supplies. The purpose of this study is to determine homeowners' reactions and the reasons for acceptance or rejection of this measure.

Acknowledgment

The task group is indebted, and has been for a number of years, to the Statistical Services Staff of the Division of Dental Public Health, USPHS, under the supervision of Grace Scholz Spitz for the collection and tabulation of the census figures included in this report.

References

1. Task Group Report. Status of Fluoridation in the United States and Canada, 1958. *Jour. AWWA*, 52:301 (Mar. 1960).
2. Natural Fluoride Content of Communal Water Supplies in the United States. USPHS report, US Govt. Printing Office, Washington, D.C. (1959).

Operators' Identification Guide to Animals Associated With Potable Water Supplies

—*William M. Ingram and Alfred F. Bartsch*—

A contribution to the Journal by William M. Ingram, In Charge, Biological Field Operations, Tech. Services Branch, and Member, AWWA Biological Infestation Committee; and Alfred F. Bartsch, Asst. Chief, Water Supply & Water Pollution Research, both of Div. of Water Supply & Pollution Control, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

LETTERS of inquiry from water utility personnel and collections of preserved animals sent by them for identification since 1950 point to the need for a simple animal identification guide such as presented here. It is designed to permit persons working in the water supply field to acquaint themselves with aquatic animals they chance to find in connection with their work. If desired, they may also identify and assign the animals to at least the broad systematic categories established by biologists, notwithstanding the inherent danger in such simplification of accepting the listed names as definitively authoritative for the animals at hand. This guide, therefore, should be looked upon as a means to satisfy human curiosity and to enable water utility personnel to determine whether the organism at hand is a moss animal or a sponge, or a segmented worm or a roundworm.

Water utility personnel whose interest may extend later to more exacting animal identification than permitted by this guide may find it an initial springboard in arousing interest in the common question "What animal is it?" As a next step, one may turn to a college or high school biology teacher who can elaborate on names and the ecology of the creatures in question. Such museums as the US National Museum, Washington, D.C.; Chicago Museum of Natural History, Chicago, Ill.; and the American Museum of Natural History, New York, N.Y., as well as many colleges, may be considered authorities to which one may turn for exact identification.

As far as now known, the animals dealt with here are not associated with human diseases. They do, however, cause nuisances because of their great abundance in (1) raw-water sources, (2) water treatment installations, or (3) finished-water reservoirs or distribution systems. More commonly, they have been seen during casual microscopic examination and have stimulated questions about their names and origins.

Publications

Two recent books, *Fresh-Water Invertebrates of the United States*[1] and *Fresh-Water Biology*,[2] deal generally with fresh-water animals in the United States. Water utility operators will find these books helpful for animal

identification. In addition, a very useful small booklet, *A Guide to the Study of Fresh-Water Biology*,[3] has been available for many years and used for identification by a goodly number of operators. In the North Central States, operators will find the mimeographed book *Taxonomic Keys to the Common Animals of the North Central States*[4] a most useful publication. A number of other publications also may be found useful and interesting.[5-12]

A USPHS booklet giving selected references on organisms associated with water treatment installations is available.[13] Another USPHS booklet, *Algae in Water Supplies*,[14] deals specifically with algae as they affect water supplies. These may be ordered from the Superintendent of Documents, Washington 25, D.C.

Ecologic Aspects

In addition to descriptive identification material, ecologic notes about the animals are included in the publications mentioned. Most of the animals dealt with are distributed throughout the continental United States. Thus, if they have invited curiosity by their appearance in large numbers in a potable water supply in New York, they could just as well have been of temporary concern to operators in Michigan, California, or Florida. The occurrence of numerous aquatic animals often can be associated with a bountiful food supply, along with other favorable factors. Thus, if any aquatic animals appear suddenly in great numbers in an open distribution reservoir, one can suspect that water treatment processes have not inhibited a bountiful food chain to which the prolific animals respond. Sometimes, a sudden animal abundance in a potable water supply may occur regardless of the food chain, as when adult midge flies, emerging from chironomid larvae (bloodworms) that live in a neighboring body of water, deposit thousands of eggs on the water surface.

Treated water of acceptable quality, pumped into open distribution reservoirs, can be degraded by dirt, lawn fertilizers, leaves, or other organic contaminants that are blown or washed into it. Such materials that increase fertility initiate food chains of organisms similar to food chains in the raw water at its source.

Invariably, filtered water will contain fewer large forms of animal life than unfiltered water used directly by the consumer. Hastings, in England, commented on "the biological consequence of omitting filtration" in his booklet titled *Biology of Water Supply*[15]:

> However free from contamination the water of a lake, or indeed any surface water may be, it should be filtered if it is to be carried to the consumer in pipes. Only the water from deep wells devoid of life can be used unfiltered with certainty that trouble will not, sooner or later, arise from living things in the pipes, although in some instances the risk is so slight that certain large cities have for many years been supplied with unfiltered, but chemically treated, water, and pipe trouble has not arisen.

But Pearsall, Gardiner, and Greenshields[16] point out that even with filtration, at least with slow sand filters, animals occasionally may be found in filtered water:

> Should a filter of sound structure be efficiently managed, the amount of organic matter entering the under-drains and other filtered-water channels will not be sufficient to support a considerable

biological population there. Nevertheless it is not rare to find organisms in these places. The commonest forms inhabiting the under-drains and culverts are a few species of free-living nematodes, a rotifer of the genus *Colurella*, crustacea such as *Gammarus* sp., and *Eucrangonyx* sp., and the repulsive looking "water louse" or "water slater" *Asellus aquaticus*, the appearance of which in a consumer's drinking water usually evokes bitter complaint. . . . Growths of sponges (*Spongilla*), "pipe mosses" (*Polyzoa*), and the so-called iron bacteria, e.g., *Crenothrix* and *Gallionella*, may also occur and are usually most troublesome on account of the obstruction they offer to the flow of water and by the corrosion they cause, especially in iron mains. To reduce the volume of complaint wire screens are sometimes interposed at some suitable point in the system, but this should be regarded as a somewhat undesirable and temporary expedient and steps should be taken to improve filtration. The presence of any of these creatures, including even the iron bacteria, in a system delivering water to the drinking vessels of the public is an indication of defect.

General Animal Classification

The classification used here follows that in *Fresh-Water Invertebrates of the United States*.[1] The 25 animals included are those that have come to the attention of the writers as being the most common inhabitants of potable water supplies; 23 additional animals that have been associated with such supplies are listed by name only under their appropriate general classification categories. Of course, there are many more animals, less frequently or obviously associated with potable supplies, than space allows for consideration here. Among the most abundant forms are the single-celled animals, protozoans, of which only four are listed, merely as examples.

Organisms in potable supplies in which interest has been expressed are as follows:

Single-celled animals (Protozoa)
- Ciliates { *Paramecium* / *Didinium*
- Amebas { *Arcella* / *Difflugia*

Sponges (Porifera)
- *Meyenia*

Hydras and jellyfish (Coelenterata)
- *Hydra*
- *Craspedacusta sowerbii* Lankester

Rotifers (Rotatoria)
- *Philodina*
- *Brachionus*

Roundworms (Nematoda)
- *Diplogaster nudicapitatus* Steiner

Moss animals (Bryozoa)
- *Paludicella*
- *Fredericella*
- *Plumatella*
- *Pectinatella*

Segmented worms (Annelida)
- *Nais*

Water fleas (Cladocera)
- *Daphnia*
- *Bosmina*

Copepods (Copepoda)
- *Cyclops*

Aquatic sow bugs (Isopoda)
- *Asellus*

Insects (Insecta)
- Bloodworm, *Chironomus* (Diptera)
- Predacious diving beetle, *Dytiscus* (Coleoptera)
- Whirligig beetle, *Gyrinus* (Coleoptera)
- Water strider, *Gerris* (Hemiptera)

Faucet snails and Asiatic clams (Mollusca)
- *Bythinia tentaculata* Linnaeus
- *Corbicula fluminea* Muller.

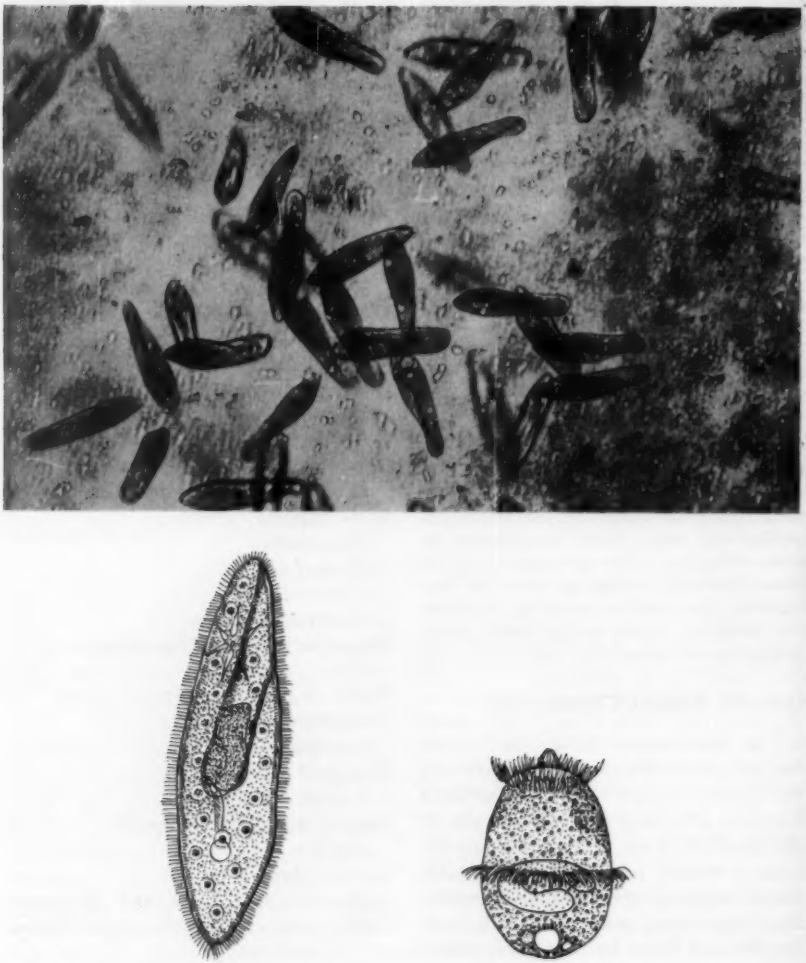


Fig. 1. Ciliate Protozoans: *Paramecium* and *Didinium*

The photograph (63×) and the drawing on the left (210×) are of Paramecium. *The drawing on the right is of* Didnium *(230×).*

CILIATES

Paramecium (Fig. 1)
Didinium (Fig. 1)

General Description

Ciliates are single-celled animals that have hundreds of small bristlelike appendages, called cilia, protruding from their bodies. The cilia beat the water to enable the animal to swim and to get food.

Paramecium is the common ciliated protozoan studied in all high school and college biology courses. Paramecia, such as the species *Paramecium caudatum* Ehrenberg, are cigar shaped or foot shaped. Some paramecia may be as long as 300 μ*; others attain a length of only 60 μ. Each has a large macronucleus and one to several compact micronuclei. The groove or peristome, which can be likened to a lip and mouth area, is long, broad, and slightly oblique.

Didinium is a ciliate with the cilia arranged in one or two girdles around the body. The mouth region is on a protrusible conelike elevation, and the macronucleus is horseshoe shaped. Individuals are 60–200 μ long.

General Ecology

Ciliates are found in all types of fresh water. They may be collected as components of plankton or scraped from water bottom oozes. They may be taken from algal mats or from the surface slime on stems of rooted aquatic plants. Forms like *Paracium* feed on bits of organic detritus and bacteria. *Didinium*, on the other hand, is carnivorous, feeding on *Paramecium* and other ciliates; it is the "tiger" of the protozoa world.

Association With Potable Supplies

Ciliates are commonly taken from uncovered finished-water reservoirs and are found in tap water of unfiltered finished-water supplies. They go unnoticed because they are so small.

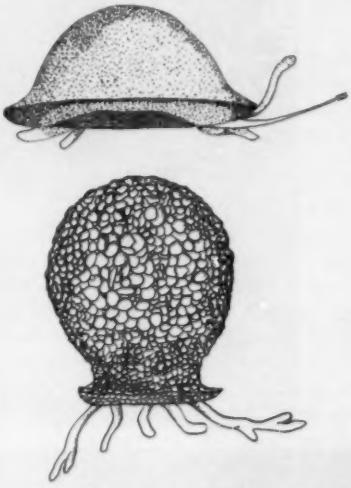


Fig. 2. Amebas: *Arcella* and *Difflugia*

The drawing on top is of Arcella *(210×); on bottom, of* Difflugia *(165×).*

AMEBAS

Arcella (Fig. 2)
Difflugia (Fig. 2)

General Description

An ameba consists of a single cell, commonly moving by means of flowing, fingerlike projections called pseudopodia or "false feet." They may be naked or have a hard covering.

* $1\mu = \frac{1}{25{,}000}$ in.

Arcella has a transparent, colorless to brown shell composed of chitin. The shell may be circular, angular, or stellate from a front view and 30–260 μ in maximum diameter. In profile, it usually appears semicircular. Slender pseudopodia, used for capturing food and crawling about, protrude from a central aperture.

Difflugia has a shell of variable shape but generally circular in cross section. The shell may be composed

Fig. 3. Sponges: *Meyenia* and *Spongilla*

The top-left photograph is of Meyenia *(0.25×); the top-right drawing, of* Spongilla *(0.17×). A flat* Spongilla *colony can be seen attached to the left portion of the aquarium wall in the bottom photograph.*

of cemented quartz sand, diatoms, and other foreign debris, thus giving it a pebbly appearance. The aperture through which the pseudopodia are thrust is terminal. The aperture may have a neck area terminated in a well formed rim or collar. The shells of bulbous forms may be as long as $230 \times 200\ \mu$ in diameter; elongate shells may have a length of $580\ \mu$ and a width of $60\ \mu$.

General Ecology

Amebas are found suspended in the water of streams and lakes or associated with the bottom ooze. They feed on organic detritus and bacteria.

Association With Potable Supplies

Amebas may be taken from uncovered finished-water reservoirs. In plankton counting, such shelled forms as *Arcella* may be mistaken for diatoms, pollen grains, or even algal colonies by the inexperienced. Walton [18] has dealt in an overall fashion with protozoans occurring in water supplies, with particular reference to those found in Ohio.

SPONGES

Meyenia (Fig. 3)
Spongilla (Fig. 3)

General Description

Identification of fresh-water sponges is extremely difficult.[19] Most species cannot be identified precisely unless asexual reproductive stages, called gemmules, are at hand. Sponges may be gray, yellowish-brown, brown, or green. Body growth may be quite variable. Sponges may form irregular incrustations over submerged objects or be round or oval, somewhat resembling the bath sponge, which is a marine animal. The body mass may measure 30–60 mm in thickness. It is quite porous, being made up of material surrounding many pores and channels running into the interior. The softer body parts are supported by straight as well as variable-shaped spicules of silica. These are used in detailed classification of sponges.

General Ecology

Sponges occur in two common forms: one that incrusts submerged surfaces, closely hugging rocks on stream bottoms; the other, more upright and branching freely. Growths frequently form tumorlike projections extending from the substrate or from sunken logs near the shores of ponds and lakes. On clear, sunny days, when the surface of the water is smooth, green sponge masses may stand out in striking contrast to the duller-colored bottom. Sponges purportedly feed on organic detritus and on microscopic organisms. One species of sponge is *Meyenia mulleri* Lieberkuhn.

Association With Potable Supplies

Pennak [20] reported occasional clogging of water pipe and conduits by sponges. Morgan [21] stated that water pipe is often lined with rough coatings a quarter of an inch or more thick, the incrustation hindering the flow through pipe or sometimes totally stopping it. Further, Morgan states that "occasionally the sponge decays and throws out impurities, giving the well known 'swamp taste' to the water." Whipple, Fair, and Whipple [22] studied sponges from pipe. They observed incrusting and ball-like growths of sponges forming unsightly masses on primary settling basins of water treatment installations.

HYDRAS

Hydra (Fig. 4)

General Description

Hydras have a columnar body as long as 25 mm, although many never attain a length greater than 15 mm. Usually five or six tentacles, arranged like umbrella ribs, surround the body opening that serves both as a mouth and an anus. Sometimes there may be as many as twelve tentacles. The animal body is translucent and may be colored whitish, grayish, brown, tan, red, or even green. Hydras are found loosely clinging to concrete basin walls or in algal mats. They move slowly by use of a pedal, or foot disc, in a gliding shuffle, or they may do handsprings as an inchworm does. Sometimes they are found floating freely in water. The tentacles have stinging cells that are used to paralyze prey. After paralyzing its prey, the hydra holds it in its tentacles and thrusts the victim into its mouth. Hydras feed especially on copepods, cladocerans, and annelids. They are voracious eaters, often stuffing themselves until they are bloated. The dark food mass in the digestive cavity can be seen through the translucent body wall with a microscope.

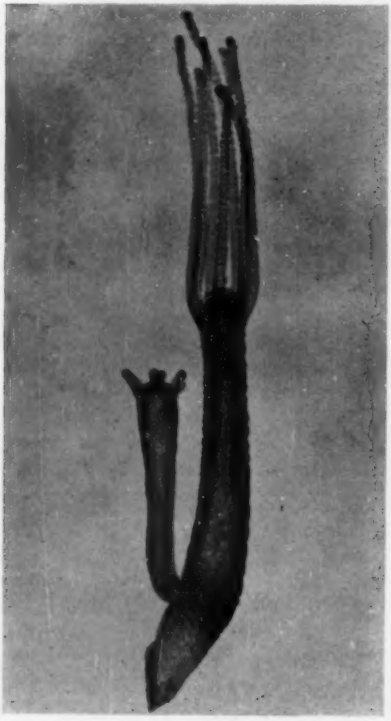


Fig. 4. Hydra: *Hydra*

The projection from the lower part of the hydra body is a bud, which will grow tentacles, drop off from the parent, and become an adult (magnification 15×).

One type of hydra reproduction is budding. The bumps often observed extending outward from the body may be such buds. These buds eventually grow tentacles, drop off from the parent, and become adults. Other types of reproduction of hydras are described in more detailed literature.

General Ecology

Hydras live in lakes and streams and are often found on the underside of leaves and sticks, where they sometimes become so abundant as to tinge the water red, as at Saranac Lake, N.Y.[21] At Quiver Lake, N.Y., Kofoid collected as many as 5,335 from a cubic yard of water during the spring of 1897.[21] As they commonly feed on small crustaceans, large populations sometimes occur when forms like *Daphnia* and *Cyclops* are numerous.

Association With Potable Supplies

Hydras have been reported to have given officials concern at a Detroit filtration plant.[23] For a few days in April and in mid-November, the abundance of hydras in the water entering the plant was correlated with the "turnover" of Lake St. Clair. Such occurrences date at least from 1923 and persisted into the early 1930's. Hydras collected in basins in such abundance that with death and decay they formed a pinkish coating on filter walls and gave off a fishy odor if the filters were not washed often. Masses of hydras reduced filter runs, also, in 1926 as much as one-third at the height of a hydra invasion.

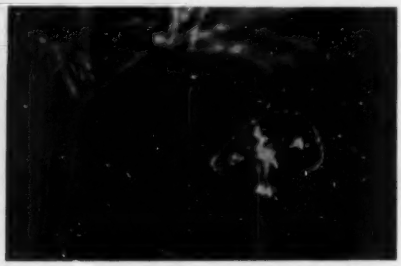
Hydras also were reported living on walls of filter beds at Auburn, N.Y. They gave a pink color to the bed walls. Their abundance was correlated with an abundance of crustaceans.[21] Baylis [24] reported hydras occurring in "considerable numbers" at Chicago's South District Filtration Plant. He stated, however, that no shortening of filter runs could be attributed to their presence.

FRESH-WATER JELLYFISH

Craspedacusta sowerbii Lancaster (Fig. 5)

General Description

Fresh-water jellyfish—translucent, umbrella-shaped animals—may vary in diameter from 5 to 25 mm. A total of 50–500 small tentacles are present around the lower margin of the body. The mouth is in the center of the lower surface, roughly resembling a broken-off handle of an umbrella.



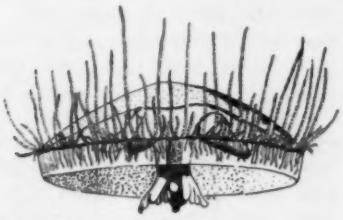


Fig. 5. Jellyfish: *Craspedacusta*

These translucent, umbrella-shaped animals may vary in diameter from 5 to 25 mm (photograph, natural size).

The animal has stinging cells, especially on the tentacles and around the mouth.

This animal is rare, having been reported from only approximately 50 localities since 1908. It appears sporadically. Millions were reported in Benson Creek, about 25 mi from Lexington, Ky., in 1916 and again in 1924, none having been observed in this creek during the intervening years. No information is available as to its food, which is assumed to be other animals.

Fresh-water jellyfish are weak swimmers, moving sideways or up and

down by contractions of the umbrella-shaped body.

General Ecology

Records show that collections of jellyfish are most common during the months July to October. The animals are found most often in water-filled quarries, small lakes, and fishponds. They can be overlooked in ordinary water sampling, because their semi-transparent bodies may blend with clear water. Records indicate that they have been found in most states east of the Mississippi River, except for northern New England and Wisconsin. Distribution in other states is sporadic, with records of occurrence in California, Oregon, Washington, Missouri, Iowa, Kansas, Arkansas, Oklahoma, and Louisiana.

Association With Potable Supplies

In July 1927, thousands of small *Craspedacusta sowerbii* emerged from a filter that was opened at the Dalecarlia Filtration Plant in Washington D.C., as reported by Meier.[25] The jellyfish persisted in the filters for 2 weeks, then disappeared abruptly. No jellyfish were found in any of the reservoirs. At the time of their appearance, the water temperature varied from 71° to 75°F. When the jellyfish were found in the filters, alum was not being used; their sudden disappearance coincided with the resumption of alum application. In reporting this filter infestation in 1940, Meier[25] stated that "their sudden visitation remains a mystery to this day."

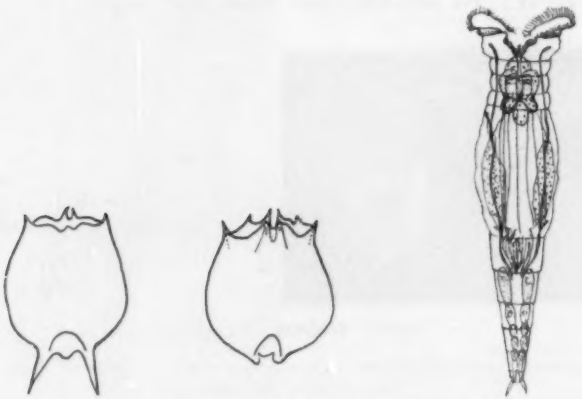


Fig. 6. Rotifers: *Brachionus* and *Philodina*

The two drawings on the left (87×) show the loricas of two species of Brachionus. *The drawing on the right is of* Philodina *(150×).*

ROTIFERS

Brachionus (Fig. 6)
Philodina (Fig. 6)

General Description

Because of difficulties in identification and classification, no attempt will

be made to describe a specific genus of rotifers or "wheeled animalcules." The two genera *Brachionus* and *Philodina* are listed because they are common and have been observed frequently in plankton when counts of algae were being made. The works by Edmondson [26] and Pennak [1] are especially helpful in rotifer identification.

The following descriptive material is included merely to emphasize certain characteristics common to most rotifers and to acquaint the operator with rotifer terminology. Structures described may not be obvious on all rotifers seen when plankton counts are made.

The rotifer body may be weakly divided into a head, trunk, and foot, with body folds separating these areas. When present, the foot typically has two projections called "toes." The body surface is covered by a "suit of armor," the cuticle. Rotifers are basically a microscopic group of animals; the great majority is 100–500 μ long.

In many genera, the cuticle, called a "lorica," is thickened and more or less rigid. Loricas are often found in water as a result of being left behind as skeletal units after the death of rotifers. The head end may bear cilia, forming a crownlike disc-shaped structure, the corona, or a ciliated funnel-like structure. The synchronized beating of cilia may give an illusional appearance of two revolving wheels attached to the head. In general, the cilia serve a dual function of obtaining food and providing locomotion by beating the water. Rotifers may also have a creeping locomotion by bending their bodies and using their toes.

The apparent coloration of the tissues is tan, brownish, or green, owing to the contents of the stomach and certain other organs, whereas the true coloration may vary from grayish to bluish, yellowish, or even pink.

General Ecology

Some rotifers exist as free-swimming or floating animals in surface water; others remain typically associated with the substrate, spending their lives as attached forms. Most are omnivorous, feeding on other small animals, organic detritus, and algae.

Certain forms appear in great abundance once a year, in autumn; others become abundant twice a year, in autumn and spring; others three times a year, in autumn, spring, and summer; while still others are perennial. The cycles, however, are quite variable within each species from year to year, and even in a single lake. About 75 per cent of the species occur within the littoral reaches of lakes.

Plankton communities may average 40–500 rotifers in a liter of water. Pennak [20] found 5,800 specimens in a single liter of unpolluted water. Rotifers with eyespots may exhibit a 24-hr vertical movement in lakes and impoundments as subsurface illumination varies. Maximum abundance in surface water occurs in the early morning, with maximum numbers found in deeper water about noon. This variable abundance in relation to light most commonly occurs in the upper 1–3 m of water.

Association With Potable Supplies

Rotifers are found commonly in uncovered finished-water reservoirs. They have been collected from the surface of filters and in various other basins of filtration plants. The following genera have been reported by Hobbs [17] to penetrate filters in England: *Diglena, Colurella, Anurea, Polyarthra,* and *Triarthra.*

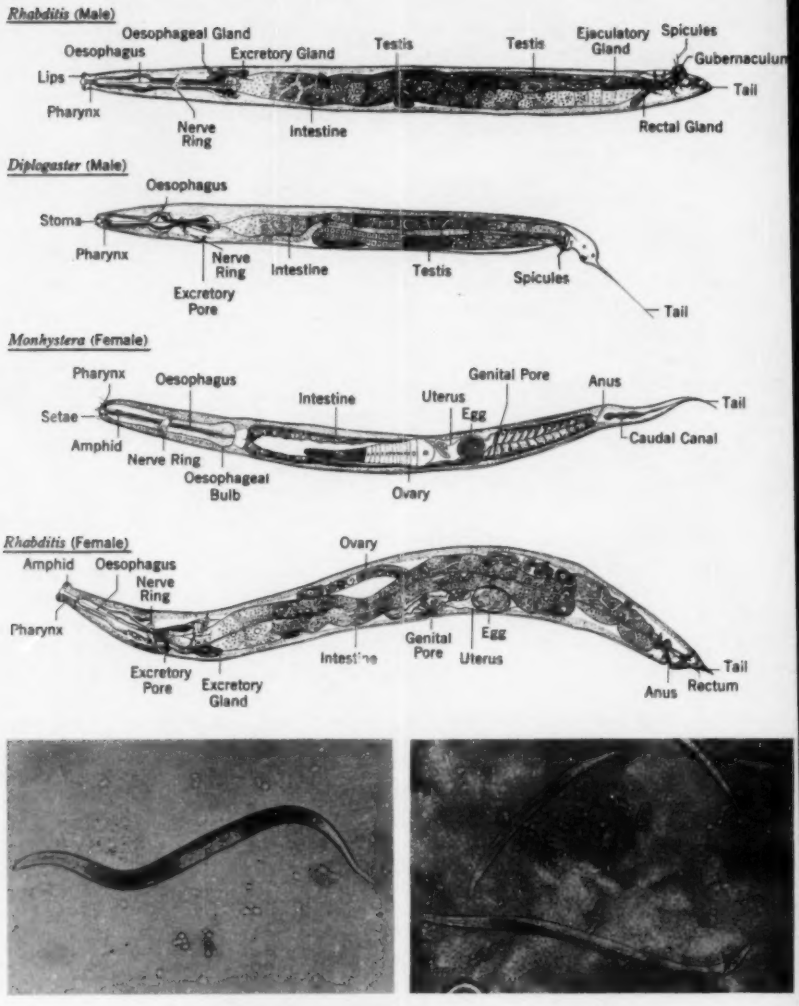


Fig. 7. Roundworms: Male and Female Nematodes

The diagram shows three species of nematodes (100×). The photograph on the left is of a female Diplogaster*; on the right, of a male* Diplogaster *(photographs magnified approximately 85×).*

ROUNDWORMS

Diplogaster nudicapitatus Steiner (Fig. 7)

General Description

Assigning names to roundworms is a most difficult task, even for the professional taxonomic zoologist. Over the last 60 years, only a few have become proficient at identifying the myriad kinds of nematodes. Thus, for present purposes, worms without any external body segmentation which are found in water should have only the large scientific category of Nematoda applied to them, leaving more precise identification to the several experts who are active today in naming such worms.

The nematode *Diplogaster nudicapitatus* Steiner is mentioned here only because it was described in an article [27] on its occurrence in both raw and finished waters:

> The body of the worm is plump and tapers anteriorly to a rather broad head. The cuticle has many longitudinal striations. The female is 0.8–1.05 mm long and is 0.05–0.06 mm wide at the greatest breadth, with a long tail which tapers to a whiplike end. The genital pore is located a little posterior to the middle of the body and the anus is subterminally located. . . . The larvae are 200–300 μ by 10–30 μ.
>
> The male is about three-fourths the size of the female. The posterior end tapers abruptly into the whiplike tail. A pair of ventrally arcuate spicules is subterminally located, leading internally to a knobbed gubernaculum. . . . The worm also has nine pairs of caudal papillae, which are visible only through phase-contrast microscopy.

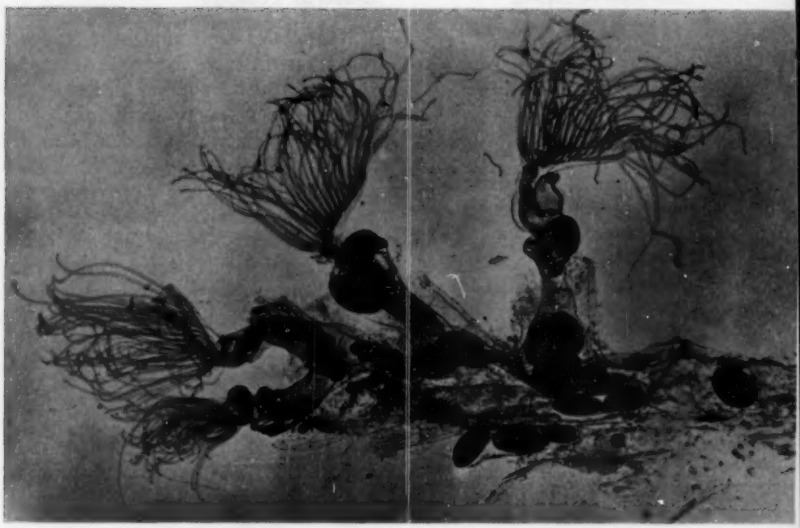
General Ecology

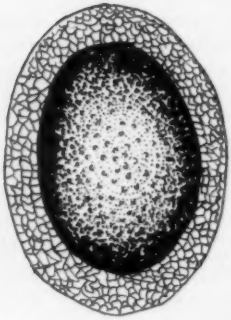
Nematodes are found in all types of waters. Actually, they are among the very common aquatic animals, although often overlooked because of their small size or excluded from animal lists because of the difficulties of identification. They apparently feed on organic debris or on bacterial and algal slimes. On agar culture plates, both adult and larval *Diplogaster nudicapitatus* were observed to feed freely on the bacteria *Proteus mirabilis* and *Aerobacter aerogenes*.[27] Eggs may hatch out in the body of the female, the larvae eating her alive and being released to the exterior to enter water only when the parent's body disintegrates. On the other hand, eggs may be released from the female's body and hatch in water.

Association With Potable Supplies

Chang and associates [27] found that raw river water could serve for the entry of nematodes into the water filtration plant. Worms found in the filter influent and effluent and in tap water were practically all larval forms. In addition to *Diplogaster nudicapitatus*, other roundworms that were dealt with were of the genera *Monhystera* and *Seinura*. A number of other publications on the subject may be found useful and interesting also.[28–30] In slow sand filter effluents of the Norwich (England) system, nematode worms, *Trilobus gracilis*, were reported by Kelly.[31]

Hobbs [17] showed in a table based on British water utility practice that other genera, such as *Dorylaimus* and *Rhabdolaimus*, grow in filter drains and pipe.





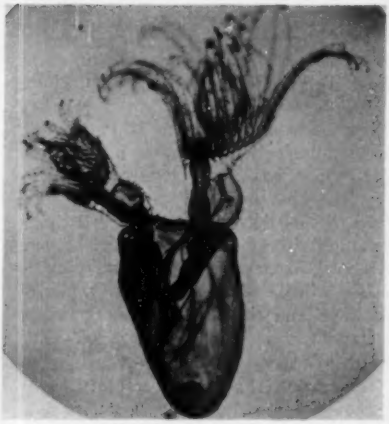


Fig. 8. Moss Animals: *Plumatella* and *Pectinatella*

The photograph on top shows a Plumatella *colony (22×). The diagram shows a statoblast of* Plumatella *(140×). On the lower right is a photograph of two individual* Pectinatella *(25×).*

MOSS ANIMALS

Paludicella
Fredericella
Plumatella (Fig. 8)
Pectinatella (Fig. 8 and 9)

General Description

Moss animals with two general body forms have been reported found in potable water supplies. One body form is vinelike, clinging to basin walls; the other is massive, occasionally resembling a large softball or football in both shape and size. The body form is made up of colonies of animals rather than being a single animal. Moss animals with the vinelike body form which have been reported in pipe have been called "pipe mosses" in the water supply field. Because individual bryozoans that make up the large colony are small, refined identification must be made with a microscope.

Vinelike moss animals are represented by the genera *Paludicella*, *Fredericella*, and *Plumatella*. Massive forms occur in the genus *Pectinatella*.

Paludicella. The colony is made up of units that are prostrate and others that are semierect. The individuals of the colony are arranged in tandem fashion among the branches. Individuals have sixteen to eighteen tentacles around the opening to the body cavity and are 2 mm long; they are club shaped. The openings in the chitinous skeleton through which individuals thrust their tentacles are square at the ends of short tubes, not terminal. Colonies form threadlike, raised patterns on submerged objects and on basin walls. Colony branches arise opposite each other from units arranged in straight lines. Colonies are pale yellow. Individuals are translucent to transparent; skeletal material is chitinous. Species example: *Paludicella articulata* Ehrenberg.

Fig. 9. Portion of *Pectinatella* Statoblast

Statoblasts are free-floating cellular units that are covered by chitinous envelopes. In Pectinatella, *statoblasts have anchorlike hooks around the periphery of the disc (100×).*

Fredericella. Branches of the colony are antlerlike, brown, and tan. Openings in the skeleton through which 17–27 tentacles are thrust are terminal at the ends of cylindrical tubes as long as 4.8 mm. Colonies are attached on submerged objects, partly creeping and partly erect. The colony sometimes forms dense clumps. Species example: *Fredericella sultana* Blumenbach.

Plumatella. The tubular-constructed colony may have incrustations on its surface. Its color is brownish, translucent to opaque. The colony is irregular in mass outline. Individuals have 30–54 tentacles at terminal ends of branches and may be alternate. Species example: *Plumatella emarginata* Allman.

Pectinatella. Individuals of a colony form small rosettes in starlike patches on the surface of a large jellylike mass. The jellylike material may vary from a watery to a solid consistency. It is translucent and may be inhabited by larvae of insects. Individuals have 50–84 tentatcles. Species example: *Pectinatella magnifica* Leidy.

With the exception of the genus *Paludicella,* the other genera discussed above have a type of asexual reproduction that may result in the formation of free-floating cellular units, called statoblasts, that are covered by chitinous envelopes. In shape they vary from elliptic to circular discs. Statoblasts in *Pectinatella* have anchorlike hooks around the periphery of the disc (Fig. 9); those of *Plumatella* and *Fredericella* are smooth without hooks. It is from statoblasts that new colonies arise. Sexual reproduction also occurs but is of no consequence to this discussion. *Paludicella* produces comparable asexual reproductive units called hibernacula. These are irregular in shape, even jagged, and brown in color.

When seen under the microscope, statoblasts and hibernacula have been mistaken for diatoms, pollen, growth stages of certain fungi, and inert particulate matter. The statoblasts, especially, are distinctive and should not be confused with diatoms, but it would be difficult to separate a hibernaculum from the ordinary debris to be found in a sample filtered from silt-laden river water. Illustrations of these asexual reproductive units should adequately permit the separation of statoblasts from other materials during the job of organism counting.

General Ecology

Basically, bryozoans are sessile animals associated with a substrate, although gelatinous colonies of *Pectinatella* may be observed floating in water on occasion. The mosslike colonies of *Plumatella* and *Fredericella* may be seen plainly with the naked eye forming mossy mats that are brownish, sometimes loosely woven and sometimes densely compacted. At times, these mats are entirely incrusting, and, on occasion, branches may extend up freely from the attachment substrate. *Paludicella* forms colonies that occasionally are hardly traceable, as compared with more clearcut *Plumatella* colonies. Colonies can be mistaken for mats of true moss, which is a plant. Several square feet of underwater surface may be covered by colonies of incrusting forms, such as *Plumatella,* or reach the size of a football or larger, as in the gelatinous colony of *Pectinatella.* Most commonly, bryozoans are found in shaded areas where light is relatively dim. Bryozoan colonies are found in relatively clean waters as

well as in stagnant waters. They may be common in rivers, streams, lakes, small ponds—attached to almost any submerged object—along shorelines, and in deeper waters. By use of the tentacles, individuals of a colony feed on both microscopic animals and plants. Statoblasts may, on occasion, be collected in plankton net hauls.

Association With Potable Supplies

Rogick [22] reported that *Plumatella, Fredericella,* and *Paludicella* have been known to clog pipe or greatly reduce pipe diameters as a result of their mat-like growths. Pennak [1] reported that these genera are found in water pipe

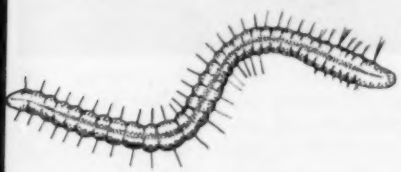


Fig. 10. Segmented Aquatic Worm: *Nais*

Worms have bristles extending from the body segments (5×).

and closed conduits. He also blames valve and meter clogging on living and dead colony masses. Occasionally, in the summer, colonies of *Pectinatella magnifica* are reported to clog screens of water intakes and grates of hydro-electric plants "so effectively that it requires the full time of a man to keep them clear." Morgan [21] stated that *Plumatella,* drawn to dark places, is found in water pipe and reservoir sluiceways.

Before filtration was commonly practiced, bryozoans apparently were a nuisance to the water supply profession. Whipple, Fair, and Whipple [22] vividly described troubles resulting from moss animals in the late 1800's and early 1900's. They mentioned that fragments of *Fredericella* passed through service pipe in the Boston area, and they reported the appearance in tap waters of bits of colonies of *Paludicella* in Brooklyn, N.Y.

SEGMENTED AQUATIC WORMS

Nais (Fig. 10)

General Description

The annelid or segmented worm is extremely difficult to identify. To apply proper generic and specific names to worms correctly, usually requires study of the internal organs, especially the reproductive system. Many of them are too small to be seen clearly with the naked eye, so that a microscope is required to bring out the details of outline and internal structure. The genus *Nais* is selected for discussion because it is a name applied most commonly to segmented worms in the water supply field. Actually, many kinds of worms found in water supplies have been incorrectly assigned to *Nais* more for convenience than for accuracy.

In the family Naididae, to which *Nais* belongs, the length of an animal may be 1.5–25 mm. The animals are smaller in diameter than an ordinary sewing needle. Adults may be translucent. Worms have bristles extending from their body segments, some short and others long and hairlike.

General Ecology

Segmented worms can be found commonly in algal masses, on submerged rooted water plants, and in the surface layer of bottom sludges. Most feed on organic detritus, passing it through the digestive tract as do

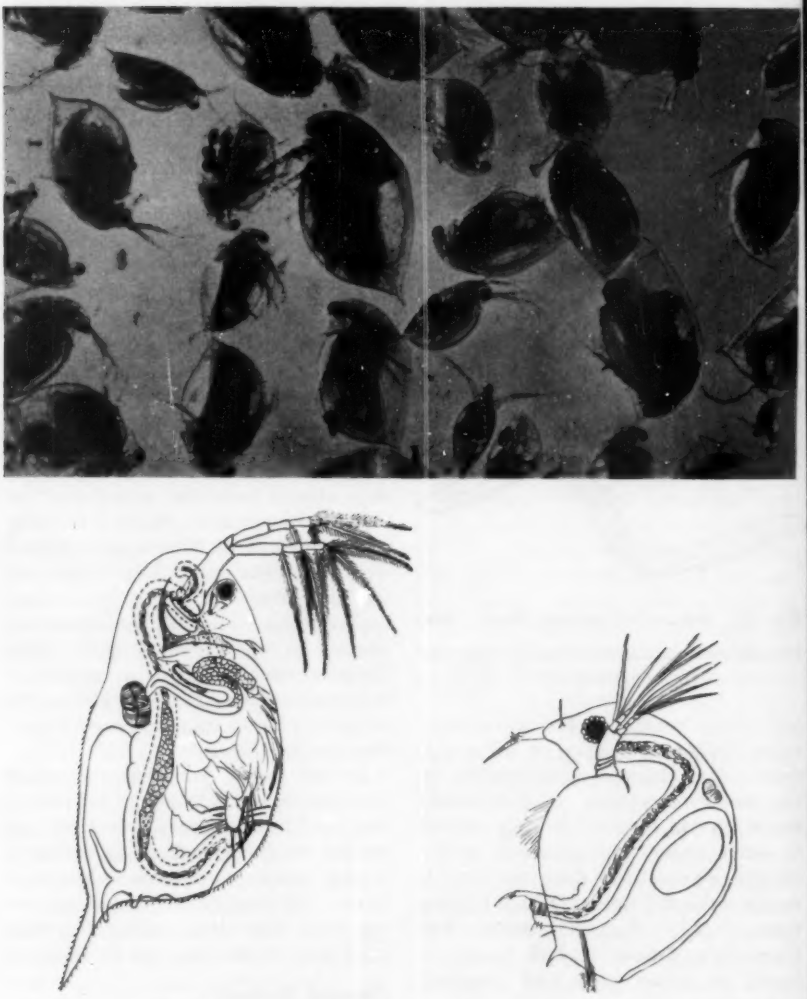


Fig. 11. Water Fleas: *Daphnia* and *Bosmina*

The photograph (10×) and the diagram on the left (35×) are of Daphnia. *The diagram on the right shows* Bosmina *(100×).*

the well known garden earthworms. Some, as *Chaetogaster diaphanus* Gruithusen, feed on small crustaceans, including cladocerans and water fleas.[21] Some live in tubes that they construct, but most are free living, moving about over the water bottom and often being swept up by water currents.

Association With Potable Supplies

Rapid sand filters, which are bound to collect organic debris in the interstices between sand grains, may present an ideal home for breeding segmented worms. Worm populations in rapid sand filter beds have been reported to necessitate washing the beds with a strong solution of caustic soda.[17] Worms have been reported to pass through slow sand filters into distribution systems, but rapid sand filters seemed to exclude their passage.[21]

Recent reports to the authors state that *Nais* has been found in unfiltered, chlorinated supplies from certain areas of California. Problems caused by them elsewhere have been described.[22]

WATER FLEAS

Daphnia (Fig. 11)
Bosmina (Fig. 11)

General Description

In the water supply field, most water fleas observed in plankton counting have been assumed to belong to the well known genera *Daphnia* and *Bosmina*. Actually, there is little point in trying to describe these genera precisely here, because of the subtleties of terminology used by professionals working on the classification of the cladocerans. But the illustrations used here will refer water utility personnel to a common *Daphnia* and a common *Bosmina*. The basic key to the Cladocera was formulated by Birge,[24] with modification by Brooks,[25] and is still authoritative. If one decides to work on the existing classification of cladocerans, he must refer to such detailed works.

In general, cladocerans are 0.2–3.0 mm long. The body is not clearly segmented. Under a microscope, the animals may appear translucent. Proper lighting reveals their internal organs covered by a bivalve shell. In side view, they may be elongated, oval, round, or angular in outline. The posterior end often has an elongate spine. A large, dark structure on the head is a compound eye, which is the animal's most prominent feature. The second pair of appendages or antennae attached to the head is very large, conspicuous, and much branched. Antennae are used like oars to propel the organism through the water. Five or six pairs of lobed, thoracic legs can be seen also, within the shell that covers the posterior end of the body. Species examples: *Daphnia pulex* Leydig and *Bosmina longirostris* O. F. Muller.

General Ecology

Cladocerans feed on organic particulate matter, bacteria, protozoans, algae, rotifers, and, sometimes, on other minute crustaceans. During optimal reproduction, as many as 200–500 individuals have been counted per liter of water. They may be found swimming freely in most bodies of water and along the edges and on bottom deposits of algal mats and rooted higher aquatic plants. They form an important part of the staple food supply of many young fish. Invariably, plank-

ton tow nets capture many cladocerans. On microscopic examination of plankton samples, they are seen to move jerkily about among algal cells.

Association With Potable Supplies

These small crustaceans can at times be observed in drinking water from unfiltered supplies. If a tumbler of water is held to the light, their translucent bodies are seen to move in a jerky fashion. They have been reported recently in finished water in distribution systems by Hart.[36] Cox [37] indicated that they are removed from potable supplies by filtration. Hobbs [17] reported that slight difficulty has been encountered from penetration of filters by *Daphnia*. Kelly [21] reported *Daphnia* in the effluents of slow sand filters.

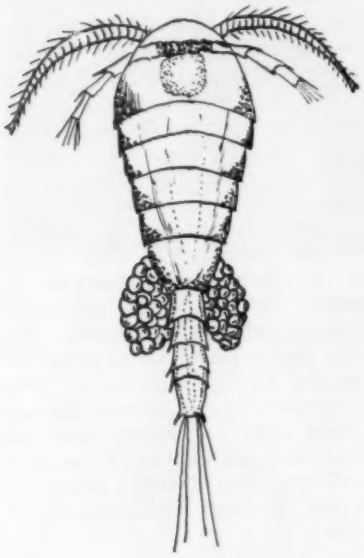


Fig. 12. Cyclops: *Cyclops*

The two oval extensions from the body of the female are ovisacs that contain eggs (30×).

CYCLOPS

Cyclops (Fig. 12)

General Description

The length of *Cyclops* (crustaceans) is 0.3–3.2 mm, the majority of them being less than 2.0 mm. Common ones are grayish, brownish, or yellowish in color. To classify the copepods accurately, the structure of the appendages must be studied in detail. The body in free-living species is divided into three distinct regions: head, thorax, and abdomen. Paired appendages are attached to the head and thorax; they are absent from the abdomen. A false "tail" terminates the abdomen. A long pair of antennae on the head is prominent.

Two oval or oblong bodies, which are relatively large when compared with the overall body size, may be observed attached to, and extending laterally from, the body of females. These are ovisacs, which contain eggs. From each egg, a larva called a nauplius emerges. The nauplius exists as a free-swimming stage prior to forming a subadult, copepodid, stage.

General Ecology

Copepods are common components of plankton. As many as 1,000 per liter of water have been counted. They feed on unicellular animals and plants and on organic debris. *Cyclops* and its relatives have a worldwide distribution in fresh water. Some species show a rhythmic cycle of vertical distribution in lakes. They are more

abundant in surface waters during the night, with correspondingly greater numbers in deeper waters during the day. They appear to be less important as fish foods than the cladocerans.

Association With Potable Supplies

Crabill [38] reported that filters at Indianapolis, Ind., kept adult copepods of the genera *Cyclops* and *Canthocamptus* from entering finished water. Their eggs, however, did pass through the filters and hatched in finished water, "so that adult forms were carried to the consumers." At the height of the infestation, as many as twenty eggs per liter were counted from finished water at the immediate effluent side of filters. This infestation was reported only from the Fall Creek filtration plant which has a 7-bil gal raw-water impounding reservoir 10 mi upstream from the plant's intake. The White River plant has no raw-water storage involved and, therefore, did not have copepod nuisances.

Fig. 13. Aquatic Sow Bug (Water Louse): *Asellus*

The animal has seven pairs of legs, the first pair with a grasping apparatus (2.2×).

Hart [36] implied that *Cyclops* may have gained entrance to finished water supplies in England by passing through filters in the egg stages. Baylis [24] noted that *Cyclops* has been taken from filter surfaces of Chicago's South District Filtration Plant. He remarked that they have not occurred in such numbers as to cause appreciably shortened filter runs. He did state, however, that other plants throughout the country have had filter runs shortened and attributed such difficulty to *Daphnia* in addition to *Cyclops*.

AQUATIC SOW BUGS (WATER LICE)

Asellus (Fig. 13)

General Description

Water lice (crustaceans) are less than 1 in. long, many commonly 0.5–0.75 in. long, and grayish or brownish in color. The body is somewhat flattened and strongly segmented, with seven pairs of legs, the first pair with a grasping apparatus. Posterior legs are longer than anterior ones.

General Ecology

The animals are found under rocks, debris, and in attached growths. Hundreds may be observed on occasion in marginal areas and on the sides of protruding rocks in small streams. They are scavengers of dead animals and also apparently feed on certain aquatic plants. Species example: *Asellus militans* Hay.

Association With Potable Supplies

Hobbs [17] reported *Asellus* found with other types of crustaceans, such as *Gammarus* and *Eucrangonyx*, in slow sand filters. It is usually present in small numbers and is troublesome to consumers only because it is visible. Pearsall, Gardiner, and Greenshields [16]

stated that the appearance of *Asellus aquaticus* Linnaeus, or water louse, in a consumer's drinking water "usually evokes bitter complaint." Hart [38] reported *Asellus* colonizing a water main in England, being able to establish residence and breeding within the distribution system. These animals have been troublesome in the Amsterdam distribution system also.[39] Holland [40] has written on eradication methods employed to rid distribution systems of the aquatic sow bug.

BLOODWORMS

Chironomus (Fig. 14)

General Description

The dipteran (fly) genus, *Chironomus,* to which most of the bloodworms have been assigned in published articles in the water supply field, is a most difficult one to understand. The bloodworms are also assigned by some entomologists to the genus *Tendipes.* The following comments are based on Johannsen's [41] studies. The difficult terminology necessary for specific classification is omitted, and positive identification is better left to the few specialists in the United States who are working on larval stages of the genus. The larva rather than the adult, which is a two-winged midge fly, has attracted most attention with regard to distribution system nuisances. In most instances, wormlike larvae from distribution systems have been ones with blood-red coloring.

Many kinds of bloodworms, such as *Chironomus plumosus* Linnaeus, are 20–25 mm in length. The head is brownish. The lateral-posterior margin of Segment 10 has a short, gill-like lobe; two pairs of long, ventral gills are on Segment 11; two pairs of anal gills are on Segment 12. To be anywhere certain of specific classification of bloodworms requires the dissection and study of the head capsule by an expert.

General Ecology

Adult chironomids, or midge flies, lay their eggs in jellylike strings enveloped by a gelatinous mass, sometimes free on the surface of water or sometimes attached to aquatic plants, stones, or twigs. Eggs are elongate oval, usually concave on one side. In addition to the blood-red larvae, other larvae may be brown, yellowish, or greenish. Wirth and Stone,[42] from information given by Townes,[43] presented interesting data on a common bloodworm:

Fig. 14. Bloodworms: *Chironomus*

The left diagram shows the pupa (3.9×); the right, the larva (2.8×).

The widespread large species *T.* [*Tendipes*] *plumosus* is probably the most important organism in the profundal zone of eutrophic lakes, where it may become as abundant as 2,500 larvae per square

meter in summer, the smaller larvae (hatched in the current season) preferring depths less than 5 meters, while the large larvae (hatched the year before) move to the greater depths. In these large lakes, there is one complete generation a year, with the peak of adult emergence in May.

Walshe [44] states that *Tendipes* (or *Chironomus*) *plumosus* Linnaeus is exceptional among the mud-dwelling larvae of the genus in its habit of spinning a salivary (mucus) net across the opening of the mud tube in which it lives. It forces water currents through the tube by body motions, the net collecting debris and an occasional algal cell, which the animal eats, net and all.

Association With Potable Supplies

Bahlman [45, 46] reported on bright-red bloodworms (*Chironomus*) in an uncovered clear well of Cincinnati's water treatment plant. Larvae moved from the clear well to emerge through faucets of residences on the distribution system. From a finished-water faucet at the filtration plant, as many as five to twenty worms were taken in 24 hr. Bahlman stated that, during the infestation, as many as ten or fifteen worms were carried by water to a bathtub. Others emerged from faucets or entered toilet bowls of a suburban family hotel. Leaves and algal growths that were associated with the formation of bottom sludge in the clear well were noted as forming an ideal habitat for bloodworm larvae. Bahlman concluded that "a complete covering of the clear-well reservoir is the only means of maintaining an aesthetic water supply."

Hechmer [47] reported bloodworms, *Chironomus plumosus*, from finished-water tanks, coagulation basins, and the surface of sand filters of water treatment installations of the Washington Suburban Sanitary District (Washington, D.C.–Maryland). None got through the filters. Bloodworms found in the finished-water tanks developed there from eggs deposited by the adult midge flies. Larvae issuing from faucets caused consumer complaints. Finally, covering the filtered-finished-water tanks did away with the bloodworm problem.

Fig. 15. Predaceous Diving Beetle: *Dytiscus*

Dytiscus *has flattened hind legs used for swimming* (3×).

Arnold,[48] in discussing generally the occurrence of insect larvae in reservoirs in California, mentioned that the only satisfactory way to control *Chironomus* in reservoirs is by construction of an insectproof roof. Flentje [49] discussed the elimination of bloodworms, which were colorless to faint green and 4–5 mm in length, from the distribution system at Alexandria, Va. The focal point of the infestation was two "clear-water storage reservoirs." Brown [50] reported chironomids found in the distribution system whose point of development was an uncovered

reservoir (because of a collapsed roof) at Stockton, Calif. The stored water originated from a well source. Flentje [51] summarized literature that dealt with various chironomid infestations, including his own experience with them. Silvey [52] also described bloodworm problems.

Hastings [15] discussed the destruction of the film on a slow sand filter in Belgium by *Chironomus* midge larval tubes at the surface of the filter. When these insects emerged, empty tubes allowed water to pass through unfiltered. On one occasion, swallows that were feeding on emerged midge adults were taken as a warning to stop filtration until a new film could be formed.

PREDACEOUS DIVING BEETLES

Dytiscus (Fig. 15)

General Description

Diving beetles range from a few millimeters to as much as 40 mm in length. Their color varies from shiny black to dark brown, often marked with bronze, dull yellow, or green. Antennae are long and threadlike, a characteristic that distinguishes them from another large water beetle family, the Hydrophilidae, which have short, clublike antennae. Like many other water beetles, they have flattened hind legs that they use for swimming. About 33 genera of Dytiscidae are known to occur in the United States.

General Ecology

Diving beetles are quite active during the day, sometimes even being attracted to lights at night. They live under water but must obtain atmospheric oxygen, which they may do on trips to the surface, thrusting the posterior tip of their bodies through the surface film. Eggs are laid on plants under water or in wet places just out of water. The beetles feed on dragon and damsel fly nymphs and on other aquatic animal morsels that they capture, including tadpoles and small fish.

Adults may fly from lake to lake. Records show that some have been caught flying 6 mi from the nearest body of water.[1]

Fig. 16. Whirligig Beetle: *Gyrinus*

The first pair of legs protrudes prominently; the other pairs are obscured in dorsal view (3.3×).

Association With Potable Supplies

Hurst [53] reported predaceous diving beetles found in uncovered distribution reservoirs in Winnipeg, Canada. The majority of individuals belonged to the genus *Dytiscus*; a few were assigned to *Cybister*. They were associated with reduced water pressure in a brewery service line, their bodies clogging a fish trap on the line. The

trap was so blocked that a pail was filled with 5 lb of beetle bodies obtained by cleaning the trap.

WHIRLIGIG BEETLES

Gyrinus (Fig. 16)

General Description

Whirligig beetles have been observed by most people who have examined fresh waters. They are the beetles that form huge schools, circling and gliding about each other in rapid, irregular curves.

The body is black and oval, with the tip of the abdomen protruding past the wing covers. The middle and hind pairs of legs are shortened and paddle-like or fan shaped and fringed; the first pair of legs protrudes far out from the side of the body. The compound eyes are divided by the insertion of antennae, resulting in one pair of eyes for vision above, and one pair for vision below, water. The third segment of the antenna is earlike and enlarged; the other segments form a spindle-shaped mass. Gyrinids vary in length from a few millimeters to a half-inch.

General Ecology

The adults carry an air supply when submerged and need to return to the surface occasionally for additional oxygen. They feed on living insects that fall into the water, as well as on dead animal matter and vegetation. Thus, they are apparently both predators and scavengers. They can fly, taking off from banks, rocks, or debris that may be above the surface of the water. Schools of them are often found in shady, sheltered spots on the surface or near shore in the vicinity of emergent vegetation.

Association With Potable Supplies

Whirligigs may be found on the surface of raw-water reservoirs or on uncovered finished-water reservoirs in parklike areas. They may form a startling surface phenomenon that will attract attention when they go through their circling gyrations at the water's edge.

Fig. 17. Water Strider: *Gerris*

The body is held aloft from the water on stiltlike legs (3.3×).

WATER STRIDERS

Gerris (Fig. 17)

General Description

Water striders, long-legged bugs, are among the most common insect inhabitants of the surface films of ponds, lakes, and pool areas of streams. The body may be 0.5 in. in length, depend-

ing on the stage of growth. Wings may or may not be present. The body is held aloft from the water on stiltlike legs. A hypodermic-needlelike beak protrudes from the front-center part of the head. The front pair of legs is considerably shorter than the middle and hind pairs.

General Ecology

Water striders are predaceous, feeding on other aquatic insects and on insects that fall into the water. They may be cannibalistic, feeding on their own kind, especially when they are susceptible just after molting. They are surface dwellers, incapable of diving below water.

Association With Potable Supplies

Water striders may be observed on the surface of water along the shores of open finished-water reservoirs.

FAUCET SNAILS

Bythinia tentaculata Linnaeus
(Fig. 18)

General Description

Adult shells of faucet snails are 9.5–15 mm long, with a maximum width of 6–7 mm. The shell is transparent to opaque, with an elevated spire. The door, or operculum, with which the animal seals itself in the shell, is toward the posterior part of the foot. Concentric rings on the operculum are obvious.

General Ecology

This gastropod is found from Vermont to Wisconsin. It has been most commonly reported in lakes. Adults crawl slowly over bottom sticks, stones, and mud, and on the undersides of leaves of aquatic plants. The animal is a browser, apparently scraping up bacterial film and algal cells with its rasplike tongue, which is called a radula.

Association With Potable Supplies

Individual snails have been reported coming from water faucets in Chicago served by unfiltered supplies taken through crib structures in Lake Michigan, and from faucets in Erie, Pa., where Lake Erie is the source of supply. Consequently, the name "faucet-snail" has been applied to this mollusk.[54-57]

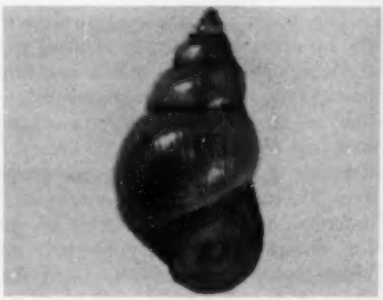


Fig. 18. Faucet Snail: *Bythinia*

The operculum, with which the animal seals itself in the shell, is toward the posterior part of the foot (4.5×).

Other snails that have been only incidental residents of potable-water supply basins without causing nuisances belong to the genera *Physa, Goniobasis, Helisoma, Lymnaea, Ancylus,* and *Pleurocera.* Ingram[57] reported meter-clogging difficulties in Singapore caused by *Melania tuberculata* Muller.

ASIATIC CLAMS

Corbicula fluminea Muller
(Fig. 19 and 20)

General Description

To date, distribution of Asiatic clams in the United States is limited to Arizona, California, Idaho, Oregon, and Washington.

The shell is about as long as it is wide and is inflated with well developed concentric sculpture lines on the valves. The color of the thin, chitinous coating over the basic calcium carbonate matrix of the valves varies from brownish black to jet black. On the interior, the coloring of the valves is dull white. Shells of large clams may be pitted by erosion. The size of adult clams in the United States attains 50 mm in length, but very young clams may be only 1 mm or 2 mm long. In Asia, adult clams as long as 83 mm have been found.

General Ecology

The Asiatic clam is a bottom-dwelling animal that buries itself in the upper surface of sand or mud bottoms, or a combination of the two. It is found in large rivers, small streams, and in lakes, apparently feeding on plankton. Free-swimming microscopic larvae are released into the water from the body of the parent, where eggs are held until they hatch.

Association With Potable Supplies

To date, difficulties with this organism have been reported only from California, where it has been associated with irrigation supplies. Nevertheless, potential troubles that the organism might cause in potable supplies if it becomes established have been pointed out.[58]

The Metropolitan Water District of Southern California at La Verne expressed concern to the senior author in 1958 relative to an infestation of Asiatic clams near the intake of the

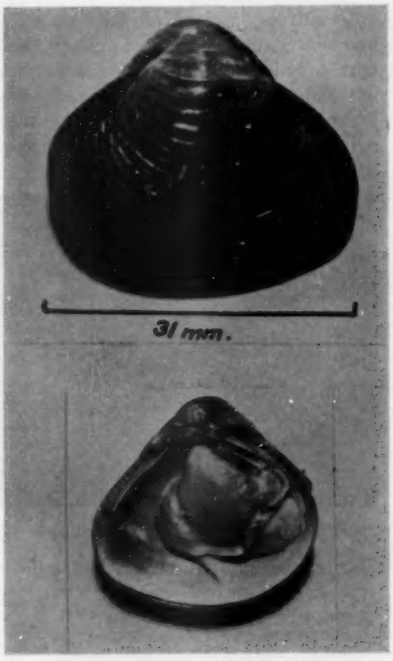


Fig. 19. Asiatic Clam: *Corbicula*

The color of the outside coating varies from brownish black to jet black. The valves on the inside (bottom photograph) are dull white (1.5×).

district's aqueduct system in Colorado River water. Potential problems from the presence of such clams are reduction in carrying capacity of pipelines and possible damage to pump impellers. Reduced carrying capacity has

now been demonstrated from the clogging of distribution systems in the irrigation network of the Coachella Valley County Water District in California. In addition, the clogging of tubes in condenser cooler units of the Tracy pumping station in California forecasts additional troubles.

In Europe, a clam, *Dreissensia polymorpha* Pallas, that can fasten itself with a holdfast to the interior of pipe has caused difficulties for years by impeding free passage of water by narrowing the pipe diameter.[57, 59, 60] Fortunately, this clam, commonly called the zebra mussel, is not found in the United States.

Fig. 20. Asiatic Clams: *Corbicula*

The specimens shown were taken from an infestation.

Acknowledgments

The authors are especially indebted to LaVerne Curry, of the Department of Biology, Central Michigan University, Mt. Pleasant, Mich., for having critically read the first draft of this publication.

Appreciation is expressed to Marshall P. Crabill, of the Indianapolis Water Co., Indianapolis, Ind., for his assistance as chairman of the Biological Infestation Committee of AWWA.

Thanks are due Minna E. Jewell, of the Department of Biology, Thornton Junior College, Harvey, Ill., for supplying a photograph of *Meyenia*; and to Shih Lu Chang, in charge of Water Treatment Evaluation Studies, Water Supply and Water Pollution Research, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, for supplying photographs, diagrams, and data on roundworms in water supplies.

The following photographs were supplied through the courtesy of General Biological Supply House, Chicago, Ill.: Fig. 1, *Paramecia*; Fig. 3, *Spongilla*; Fig. 4, *Hydra*; Fig. 5, *Craspedacusta;* Fig. 8, *Plumatella* and *Pectinatella*; Fig. 9, *Pectinatella* statoblast; and Fig. 11, *Daphnia.*

References

1. Pennak, R. W. *Fresh-Water Invertebrates of the United States.* The Ronald Press, New York (1953).
2. Edmondson, W. T. (ed.). Ward & Whipple's *Fresh-Water Biology.* John Wiley & Sons, New York (2nd ed., 1959).
3. Needham, J. G. & Needham, P. R. *A Guide to the Study of Fresh-Water Biology.* Comstock Publishing Co., Ithaca, N.Y. (1941).
4. Eddy, S. & Hodson, A. C. *Taxonomic Keys to the Common Animals of the North Central States Exclusive of Parasitic Worms, Insects, and Birds.* Burgess Publishing Co., Minneapolis (Rev., 1950).
5. Joint Discussion. Methods of Controlling Aquatic Growths in Reservoirs. *Jour. AWWA,* 46:1141 (Nov. 1954).
6. Rafter, G. W. *The Microscopical Examination of Potable Water.* D. Van Nostrand Co., New York (1892).
7. Suckling, E. V. Thresh, Beale, and Suckling's *The Examination of Waters and Water Supplies.* Blakiston Co., Philadelphia (5th ed., 1943).

8. SCOURFIELD, D. J. & HARDING, J. P. *A Key to the British Species of Freshwater Cladocera, With Notes on Their Ecology.* Freshwater Biological Assn. of the British Empire, Scientific Publication 5, Ambleside, Westmorland, England (2nd ed., 1958).
9. PETERSON, A. *Larvae of Insects. II. Coleoptera, Diptera, Nemoptera, Siphonaptera, Mecoptera, Trichoptera.* Edwards Bros. Inc., Ann Arbor, Mich. (1951).
10. COX, C. R. *Water Supply Control.* Bul. 22, New York State Dept. of Health, Albany, N.Y. (1952).
11. USINGER, R. L. (ed.). *Aquatic Insects of California, With Keys to North American Genera and California Species.* Univ. of California Press, Berkeley and Los Angeles (1956).
12. VAN NAME, W. G. *The American Land and Fresh-Water Crustacea.* Bul. 71, American Museum of Natural History, New York (1936).
13. INGRAM, W. M. *Handbook of Selected Biological References on Water Pollution Control, Sewage Treatment, and Water Treatment.* USPHS Publication 214, Washington, D.C. (Rev., 1957).
14. PALMER, C. M. *Algae in Water Supplies.* USPHS Publication 657, Washington, D.C. (1959).
15. HASTINGS, A. B. *Biology of Water Supply.* British Museum of Natural History, Economic Series 7-A, London, England (1937).
16. PEARSALL, W. H.; GARDINER, A. C.; & GREENSHIELDS, F. *Freshwater Biology and Water Supply in Britain.* Freshwater Biological Assn. of the British Empire, Scientific Publication 11, Ambleside, Westmorland, England (1946).
17. HOBBS, A. T. (ed.). *Manual of British Water Supply Practice.* Inst. of Water Engrs., W. Heffer & Sons Ltd., Cambridge, England (1950).
18. WALTON, L. B. *Studies Concerning Organisms Occurring in Water Supplies, With Particular Reference to Those Found in Ohio, Part I.* Ohio Biol. Survey Bul. 24, Ohio State Univ. Press, Columbus, Ohio (1930).
19. JEWELL, M. Porifera. *In* Ward & Whipple's *Fresh-Water Biology.* John Wiley & Sons, New York (2nd ed., 1959). p. 298.
20. PENNAK, R. W. Annual Limnological Cycles in Some Colorado Reservoir Lakes. *Ecol. Monographs,* 19:233 (1949).
21. MORGAN, A. H. *Fieldbook of Ponds and Streams.* G. P. Putnam's Sons, New York (1930).
22. WHIPPLE, G. C.; FAIR, G. W.; & WHIPPLE, M. C. *The Microscopy of Drinking Water.* John Wiley & Sons, New York (4th ed., 1927).
23. HUDGINS, BERT. Turbidity, Plankton, and Mineral Content of the Detroit Water Supply. *Jour. AWWA,* 23:435 (Mar. 1931).
24. BAYLIS, J. R. Microorganisms That Have Caused Trouble in the Chicago Water System. *Pure Water,* 9:47 (1957).
25. MEIER, F. E. Plankton in the Water Supply. 1939 Rept. of Smithsonian Inst., Washington, D.C. (1940). p. 393.
26. EDMONDSON, W. T. Rotifera. *In* Ward & Whipple's *Fresh-Water Biology,* John Wiley & Sons, New York (2nd ed., 1959). p. 420.
27. CHANG, S. L., ET AL. Occurrence of a Nematode Worm in a City Water Supply. *Jour. AWWA,* 51:671 (May 1959).
28. CHANG, S. L.; WOODWARD, R. L.; & KABLER, P. W. Survey of Free-Living Nematodes and Amebas in Municipal Supplies. *Jour. AWWA,* 52:613 (May 1960).
29. CHANG, S. L., ET AL. Survival, and Protection Against Chlorination, of Human Enteric Pathogens in Free-Living Nematodes Isolated From Water Supplies. *Am. J. Trop. Med. Hyg.,* 9:2:136 (1960).
30. CHANG, S. L. Proposed Method for Examination of Water for Free-Living Nematodes. *Jour. AWWA,* 52:695 (Jun. 1960).
31. KELLY, S. N. Infestation of the Norwich, England, Water Systems. *Jour. AWWA,* 47:330 (Apr. 1955).
32. ROGICK, M. D. Bryozoa. *In* Ward & Whipple's *Fresh-Water Biology,* John Wiley & Sons, New York (2nd ed., 1959). p. 495.
33. BELL, R. J. Problems Caused by the Presence of Nais Worms and Other

Organisms in the Public Water Supply of Norwich. *J. Waterworks Officers Assn.*, 4:4:119 (1955).

34. Birge, E. A. The Water Fleas (Cladocera). *In* Ward & Whipple's *Fresh-Water Biology.* John Wiley & Sons, New York (1918). p. 676.
35. Brooks, J. L. Cladocera. *In* Ward & Whipple's *Fresh-Water Biology.* John Wiley & Sons, New York (2nd ed., 1959). p. 587.
36. Hart, K. M. Living Organisms in Public Water Mains. *Jour. Inst. Munic. Engrs.*, 83:10:324 (1957).
37. Cox, C. R. *Laboratory Control of Water Purification.* Case-Shepperd-Mann Publishing Corp., New York (1946).
38. Crabill, M. P. Biologic Infestation at Indianapolis. *Jour. AWWA,* 48:269 (Mar. 1956).
39. Van Heusden, G. P. H. *Asellus aquaticus* in the Amsterdam Distribution Mains. *Water (The Hague),* 32:109 (1948).
40. Holland, G. J. The Eradication of *Asellus aquaticus* From Water Supply Mains. *J. Inst. Water Engrs.*, 10:3:221 (1956).
41. Johannsen, O. A. *Aquatic Diptera. IV. Chironomidae: Subfamily Chironominae.* Memoir 210, Cornell University Agricultural Experiment Station, Ithaca, N.Y. (1937).
42. Wirth, W. W. & Stone, A. Aquatic Diptera. In *Aquatic Insects of California, With Keys to North American Genera and California Species.* Univ. of California Press, Berkeley and Los Angeles (1956). p. 372.
43. Townes, H. K., Jr. *VI. Studies on the Food Organisms of Fish.* Biol. Survey of Allegheny and Chemung Watersheds. Suppl. 27th Annual Rept., New York State Conservation Dept., Albany, N.Y. (1938). p. 162.
44. Walshe, B. M. The Feeding Habits of Certain Chironomid Larvae (Subfamily Tendipedinae). *Proc. Zool. Soc., London, England,* 121:63 (1951).
45. Bahlman, C. *Larval Contamination of a Clear Water Reservoir.* 11th Annual Rept., Ohio Conf. on Water Purification. State Dept. of Health, Columbus, Ohio (1931). p. 56.
46. Bahlman, C. Larval Contamination of a Clear-Water Reservoir. *Jour. AWWA,* 24:660 (May 1932).
47. Hechmer, C. A. *Chironomus* in Water Supply. *Jour. AWWA,* 24:665 (May 1932).
48. Arnold, G. E. Plankton and Insect Larvae Control in California Waters. *Jour. AWWA,* 28:1469 (Oct. 1936).
49. Flentje, M. E. Elimination of Midge Fly Larvae With DDT. *Jour. AWWA,* 37:1053 (Oct. 1945).
50. Brown, K. W. Experiences with Well Water in an Uncovered Reservoir. *Jour. AWWA,* 25:337 (Mar. 1933).
51. Flentje, M. E. Control and Elimination of Pest Infestations in Public Water Supplies. *Jour. AWWA,* 37:1194 (Nov. 1945).
52. Silvey, J. K. G. Bloodworms in Distribution Systems. *Jour. AWWA,* 48:275 (1956).
53. Hurst, W. D. Predaceous Diving Beetles in Winnipeg's Water Supply. *Jour. AWWA,* 37:1204 (Nov. 1945).
54. Baker, F. C. *The Mollusca of the Chicago Area. II. The Gastropoda.* Bul. 3, Natural History Survey, Chicago Academy of Sciences, Chicago (1902). p. 137.
55. Sterki, V. Civilization and Snails. *The Nautilus,* 24:9:98 (1911).
56. Goodrich, C. *The Mollusca of Michigan.* Michigan Handbook Series 5, Univ. of Mich., Ann Arbor, Mich. (1932).
57. Ingram, W. M. Snail and Clam Infestations of Drinking-Water Supplies. *Jour. AWWA,* 43:258 (Mar. 1956).
58. Ingram, W. M. Asiatic Clams as Potential Pests in California Water Supplies. *Jour. AWWA,* 51:363 (Mar. 1959).
59. Clarke, K. B. The Infestation of Water Works by *Dreissensia polymorpha,* a Fresh-Water Mussel. *J. Inst. Water Engrs.*, 6:5:370 (1952).
60. Greenshields, F. & Ridley, J. E. Some Researches on the Control of Mussels in Water Pipes. *J. Inst. Water Engrs.*, 11:3:300 (1957).

Effect of Fish Poisons on Water Supplies

Part 1. Removal of Toxic Materials

Jesse M. Cohen, Lawrence J. Kamphake, Armond E. Lemke, Croswell Henderson, and Richard L. Woodward

A contribution to the Journal by Jesse M. Cohen, Chemist; Lawrence J. Kamphake, Chemist; Armond E. Lemke, Biologist; Croswell Henderson, Biologist; and Richard L. Woodward, Chief, Eng. Sec., all of Water Supply & Water Pollution Research Branch, Robert A. Taft San. Eng. Center, Cincinnati, Ohio. *This is the first of three articles on the effect of fish poisons on water supplies. Parts 2 and 3, to be published in the Journal, deal with odor problems and a field study, respectively.*

THE recreational use of Class C upstream reservoirs was accepted in a recent statement of policy by the AWWA Board of Directors on Jan. 26, 1958. The board stated that "recreation is considered permissible under appropriate sanitary regulations."[1]

Sport fishing is one of the more popular recreational uses of reservoirs. To increase the attractiveness of this sport, practically all states have undertaken fish management practices. Managers of fisheries sometimes find it expedient to remove an entire fish population from a body of water[2] to eliminate stunted populations or coarse fish and to enable restocking with fry or fingerlings of suitable species. The young fish, freed from predation and competition for food, rapidly grow and increase in numbers, providing superior sport fishing.

Much work has been done on the development of suitable piscicides, until today there are many commercial preparations on the market. Cost, ease of application, safety, and effectiveness in destroying fish populations are the major considerations in the selection of a compound.

The deliberate addition of a fish toxicant to a water supply source requires careful appraisal of its effect on water quality and safety. The practice demands consideration of:

1. Toxicity of active agents to humans, other mammals, and to fish in household aquariums
2. Effects of fish poison formulations and components on water treatment processes and, conversely, the effects of treatment on these compounds
3. Tastes and odors produced by the components of the formulations
4. Effects on water quality that may result from decomposing fish.

Toxicity of Rotenone and Toxaphene

The principal toxic agents in fish poison formulations in common use are rotenone and toxaphene.

Rotenone in mammals. The acute toxicity of rotenone when given orally to mammals is unusual in that toxic concentrations vary widely among species[3,4]: approximately 60 mg/kg for

guinea pigs, 130 mg/kg for albino rats, 1.5 g/kg for rabbits, and 3 g/kg for dogs.[5] Acute single oral doses result in severe irritation of the gastrointestinal tract. In dogs, cats, and pigeons, emesis accompanies a toxic dose. On an acute oral basis, rotenone would be classed, according to a conventional system, as being nearly "highly toxic" for the guinea pig but only "slightly toxic" for the rabbit and dog.

Rotenone is far more acutely toxic when administered in other ways, either intraperitoneally or intravenously. A dose of 2 mg/kg is the acute LD_{50} * for the guinea pig intraperitoneally; 0.65 mg/kg, for the dog and cat intravenously, when the rotenone is administered in ethylene glycol. For the dose administered, ethylene glycol was considered to be noninjurious in control animals.[5]

When chronically administered during a 2-year period in the diet of rats, rotenone produced necrosis of the liver in a concentration of only 5 mg/l.[6] For the same degree of tissue damage, about two times the dose of mercuric acetate, a well recognized cellular poison, would be required. When 150 mg/kg rotenone was administered in guinea pig food, fetuses of pregnant guinea pigs either failed to survive until birth or died shortly thereafter.[5]

Because no reports exist of rotenone poisoning in man, man is assumed to be one of the more highly resistant species. The fact that man has eaten fish killed by rotenone unfortunately provides no evidence on this point, because the peculiar injury of rotenone to the gills of fish makes it doubtful that any significant amount would enter the fleshy part of the fish that is eaten. The fact that rotenone has been used as a spray on edible foods likewise provides no evidence of its lack of toxicity for man. The instability of rotenone in air and sunlight causes the destruction of a major portion of the residue on such foods before they are eaten.

Toxaphene in mammals. For mammals, toxaphene is one of the more toxic of the chlorinated-hydrocarbon insecticides. The acute oral LD_{50} for rats is about 40 mg/kg; for dogs, 10–15 mg/kg. In chronic feeding tests, dogs fed 60 mg/l toxaphene in the diet for 106 days showed degenerative changes in the liver and other organs.[7]

Studies of Fish Poisons

In addition to toxaphene and rotenone, the common formulations contain solvents of unknown chemical composition and toxicity. Although there is little likelihood that these formulations would cause toxic manifestations in humans when used in the concentration needed to kill fish, they are distinctly undesirable in drinking water and should be removed or chemically altered in order to produce a finished water of good quality. As little information is available in the literature on the ability of water treatment processes to remove or alter these materials, the following laboratory investigations were made on fish poison formulations and their components:

1. Removal by activated carbon
2. Chemical detoxification by chlorine and chlorine dioxide
3. Removal by alum coagulation
4. Production and removal of odors.

Traditionally, the preferred fish poison has been derris,[8] ground root of cube, or rotenone,[9, 10] which may be extracted from these plant materials.

* A dose that is lethal for 50 per cent of the test subjects.

Difficulty in handling and evenly applying powdered root and the high cost of rotenone have led to the development of various commercial formulations that incorporate rotenone, rotenoid extractives, various hydrocarbon solvents, wetting agents, and inert materials such as clay. Such fish poisons as toxaphene and such synergists as sulfoxide (n-octyl sulfoxide of isosafrole) have also been employed.

These fish poisons and formulations were selected for study:

1. Rotenone *
2. Toxaphene †
3. Powdered cube root ‡
4. Technical-grade sulfoxide,‡ containing a minimum of 88 per cent sulfoxide (n-octyl sulfoxide of isosafrole) and a maximum of 12 per cent related compounds
5. Formulation A, containing the active ingredients 2.0 per cent rotenone and 7.0 per cent toxaphene
6. Formulation B, containing the active ingredients 5 per cent rotenone and 15 per cent other cube extractives
7. Formulation C, containing the active ingredients 2.5 per cent rotenone, 5 per cent cube extractives, and 2.5 per cent sulfoxide
8. Formulation D, containing the active ingredients 5 per cent rotenone and 10 per cent other cube extractives.

These formulations contain, in addition to the active poison, inert materials such as solvent, emulsifying agent, or mineral carrier. All of the formulations were studied at concentrations of 2.0 mg/l. Lesser concentrations, depending on the aqueous solubility, were used for the components.

* Chemically pure, obtained from Chemical Insecticide Corp., Metuchen, N.J.

† Reference standard containing 68 per cent chlorine, obtained from Hercules Powder Co., Wilmington, Del.

‡ Obtained from S. B. Penick & Co., New York, N.Y.

Residue Analysis

Initial attempts to use chemical methods for quantitative determination of rotenone and toxaphene in water proved unsuccessful with the low concentrations involved. A bioassay, based on the extreme sensitivity of fish to these compounds, was used to determine the amount of compound remaining after various treatments.

The validity of bioassays with various test animals is well documented, and excellent reviews have been published by Yun-Pei-Sun [11] and Dewey.[12] The technique for this laboratory study consisted of establishing a standard curve relating concentration of chemical to time of loss of equilibrium of 50 per cent of the test fish. When fish were introduced into unknown concentrations under the test conditions, quantitative determinations of the concentrations could be obtained by reference to the standard curve.[13]

In this study, standard curves were prepared with the use of a logarithmic series of concentrations—for example, 0.1, 0.18, 0.32, 0.56, and 1.00 mg/l of fish poison in the test water. Five fathead minnows (*Pimephales promelas*) of fairly uniform size, 2–2.5 in. long and weighing 1–1.5 g each, were added to duplicate 10-liter quantities of each concentration in 5-gal, wide-mouth glass bottles. The temperature was maintained at 25°C. Observations were made of the time necessary for 50 per cent of the fish to lose equilibrium. Time was then plotted against concentration on log-log paper. Typical standard curves obtained for pure compounds are shown in Fig. 1. It is immediately apparent that fish are highly sensitive to rotenone and

much less so to sulfoxide. Analyses for residues of rotenone can easily be made for concentrations as low as 0.006 mg/l.

The degree of treatment needed for the removal of fish poisons in a raw water supply was based on the assumption that the finished water would contain no detectable toxicity to the test fish. In this study, removal of toxicity was considered to be complete when the residual concentration of toxicants was numerically one-half of the 96-hr TL_m (median tolerance limit) value for these compounds. The TL_m value was determined according to Doudoroff and associates [14] and is defined as the concentration of toxicant at which 50 per cent of the test fish are able to survive. One-half the 96-hr TL_m concentration is an arbitrary value selected for computation purposes. These concentrations are presumed to be nontoxic to fish. The values for all the fish poisons and components tested are listed in Table 1, along with the concentration representing one-half the 96-hr TL_m value.

Solubility of Toxicants

Both rotenone and toxaphene, the principal toxicants in commercial formulations, have been reported as being practically insoluble in water. The solubility of rotenone has been reported by Jones and Smith [15] to be 0.16 mg/l. No data were available for the solubility value of toxaphene.

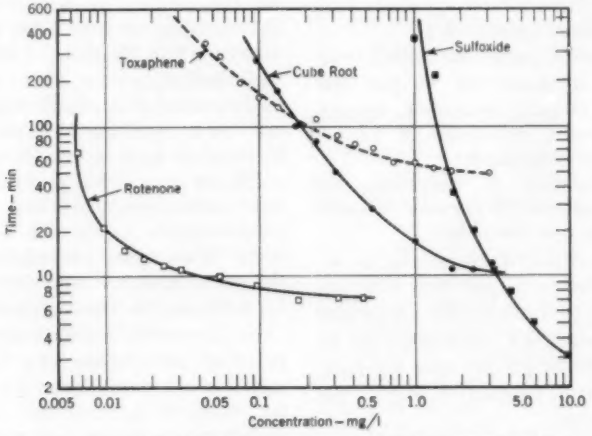


Fig. 1. Concentration-Response Curves for Pure Fish Poisons

Fish are highly sensitive to rotenone, much less so to sulfoxide.

In order not to exceed the solubility of these toxicants in the experimental work, values for both in distilled water at 25°C were determined by suspending a large excess of each toxicant in distilled water and stirring for several hours at the constant temperature of 25°C. Undissolved material was removed by filtration through a molecular filter with a pore size of 0.45 μ. The concentration of each toxicant in the filtrate was obtained by fish bio-

assay. Solubility values obtained in this manner were 0.4 mg/l and 0.17 mg/l for toxaphene and rotenone, respectively. Because of their extreme toxicity to fish, the very low water solubility of these materials is not a deterrent to their use as a fish poison.

In the experimental work the initial concentration of toxicant never exceeded these solubility values. The use of 2.0 mg/l of commercial formulation in all instances yielded concentrations of rotenone or toxaphene well below the aqueous solubility of these compounds.

Activated-Carbon Treatment

Treatment with activated carbon offers the water plant one of the most effective processes for removing small amounts of organic material. Hence, this process of removing fish poisons from raw water was studied in some detail.

Test water in all of the experimental work was a clear, hard, highly mineralized spring water, diluted 1 to 4 with distilled water. Chemical characteristics were pH, 8.3; alkalinity, 80 mg/l; hardness, 90 mg/l; and turbidity, 0.5 unit. The activated carbon * employed was a grade widely used in water treatment. All tests were made at ambient temperatures of 23–26°C.

The laboratory procedure consisted of adding varying amounts of carbon to fixed concentrations of contaminant. The suspensions were stirred rapidly for 30 min at 25°C. Carbon was removed from suspension by filtration through a glass column packed with fine glass wool. (Tests had shown that glass wool does not remove detectable amounts of fish poison.) The filtrate was analyzed by fish bioassay for residual poison. Data were then used to plot an adsorption isotherm according to Freundlich's equation, usually written as:

$$\frac{X}{M} = KC^{\frac{1}{n}} \quad \ldots\ldots\ldots\ldots (1)$$

in which X is equal to the units of adsorbate held by the carbon; M, the carbon weight by which adsorption was effected; and C, concentration of substance remaining unadsorbed at equilibrium. The two parameters K and $\frac{1}{n}$ are particular to the system—

TABLE 1

Acute Toxicity Concentrations of Fish Poisons Affecting Fathead Minnows

Toxicant	96-hr TL_m mg/l	½ 96-hr TL_m mg/l
Toxaphene	0.013	0.007
Rotenone	0.006	0.003
Cube root	0.066	0.03
Sulfoxide	0.74	0.37
Formulation A	0.10	0.05
Formulation B	0.066	0.03
Formulation C	0.066	0.03
Formulation D	0.10	0.05

that is, particular to both the carbon used and the nature of the adsorbate. The equation thus correlates adsorbate removed per unit weight of carbon, $\frac{X}{M}$, with concentration of adsorbate remaining in solution at equilibrium C. The equation in logarithmic form appears as:

$$\log \frac{X}{M} = \log K + \frac{1}{n} \log C \ldots\ldots (2)$$

which is an equation of a straight line having a slope of $\frac{1}{n}$ and an intercept of K at $C = 1$.

* Aqua Nuchar A, made by West Virginia Pulp & Paper Co., Tyrone, Pa.

Typical raw data used to construct a carbon adsorption isotherm are shown in Table 2, for which a toxaphene solution, 0.30 mg/l, was treated with different amounts of carbon. These data, when plotted on log-log paper, produce a straight line. Calculation of the parameters K and $\frac{1}{n}$ for this line then provides the means to predict the dose of carbon required to reduce any concentration of toxaphene to any desired level. Carbon adsorption isotherms were obtained for the commonly used toxicants (Fig. 2, Table 3) and for the commercial fish poison formulations (Fig. 3, Table 4).

The usefulness of the Freundlich equation (Eq 1) and the isotherm lies in the computation and graphs that may be derived from them. Thus, for day-to-day plant use, it may be desirable to know the amount of carbon required to reduce any quantity of fish poison to a predeterminel level. This is done by taking advantage of a characteristic of the Freundlich equation. If for X, use is made of its equivalent $C_o - C_f$—in which C_o equals the initial concentration of poison, and C_f equals the permissible residual poison—the equation then becomes:

$$\frac{C_o - C_f}{M} = KC_f^{\frac{1}{n}} \quad \ldots\ldots\ldots (3)$$

This equation is linear when M is plotted against C_o on ordinary coordinate paper.

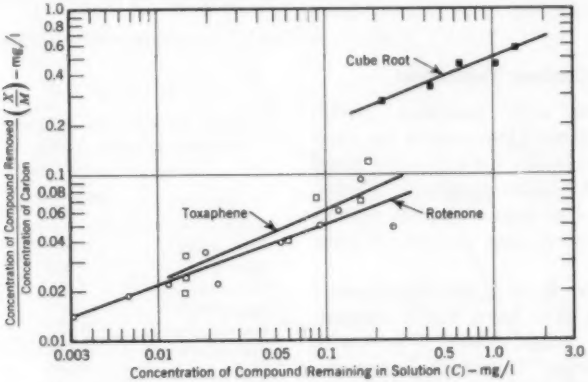


Fig. 2. Carbon Adsorption Isotherms for Pure Fish Poisons

See Table 3 for initial concentrations and parameters.

These computations were made for all the pure components and for the fish poison formulations, with the use of the parameters derived graphically from the adsorption isotherms shown in Fig. 2 and 3. The value for C_f, or permissible residual concentration of fish poison at equilibrium following carbon treatment, was taken as one-half the 96-hr TL_m values (Table 1). The plots in Fig. 4 give the amounts of carbon required to reduce any concentration of fish poison to the selected permissible residual concentration.

TABLE 2

*Adsorption of 0.30 mg/l Toxaphene by Activated Carbon**

M	C	X	$\frac{X}{M}$
Carbon Concentration *mg/l*	Toxaphene Residual *mg/l*	Toxaphene Adsorbed *mg/l*	Toxaphene Adsorbed per mg/l Carbon *mg/l*
0	0.30		
1.0	0.18	0.12	0.12
2.0	0.16	0.14	0.07
3.0	0.085	0.215	0.072
6.0	0.058	0.242	0.040
9.0	0.014	0.286	0.032

* For explanation of letter symbols, see Eq 1 and 2. Value of parameters: $K = 0.16$; $\frac{1}{n} = 0.42$.

Amounts of carbon required for toxaphene and rotenone are similar. Among the commercial fish poisons, Formulation A is the most easily removed, 8.8 mg/l carbon being required to reduce 2.0 mg/l of the formulation to 0.05 mg/l. The natural product, cube root, is also easily removed. At the other extreme, it would require 26.4 mg/l carbon to reduce Formulation B to a residual of 0.03 mg/l.

Chlorine Treatment

Many investigators have observed that rotenone is easily oxidized when exposed to air and light.[8] It is also readily oxidized by such chemical agents as potassium permanganate. Lawrence[16] demonstrated that 2.0 mg/l potassium permanganate can detoxify 1.0 mg/l of a fish poison* equivalent to 0.05 mg/l rotenone. Oxidation with permanganate is rapid. Fish survived in water to which rotenone and potassium permanganate were added at the same time. As chlorination is common in practically all water treatment plants, this process was studied for its effect on the fish poisons that include the pure compounds and the commercial formulations.

Varying amounts of chlorine were added to test water (same procedure as for carbon experiments) containing known amounts of fish poisons, and the solutions were allowed to stand at a constant temperature of 25°C. At the end of varying times of contact, sufficient sodium thiosulfate was added for dechlorination purposes, and the water was then subjected to fish assay to determine residual fish poison.

Typical laboratory data for rotenone are shown in Table 5. In these tests 0.1 mg/l rotenone was treated with varying amounts of chlorine solution for three different periods of contact at 25°C. The solutions varied in pH from 7.2 to 8.3. It is clear from these data that the effectiveness of chlorine as a detoxification agent is dependent on both the dose and time of contact. To reduce an initial concentration of rotenone of 0.1 mg/l to 0.005 mg/l or less requires 38.5, 29.5, and 11.0 mg/l chlorine at contact times of 15, 60, and 180 min, respectively.

TABLE 3

*Initial Concentrations and Parameters for Pure Fish Poisons**

Compound	Initial Concentration *mg/l*	Parameters	
		K	$\frac{1}{n}$
Toxaphene	0.3	0.16	0.42
Rotenone	0.1	0.12	0.36
Cube root	2.5	0.51	0.40

* Values related to Fig. 2.

* Noxfish, made by S. B. Penick & Co., New York, N.Y.

These data may also be plotted, as shown in Fig. 5, to provide, by extrapolation, an estimation of the amount of chlorine required to reduce the toxicity of 0.1 mg/l rotenone to one-half the 96-hr TL_m. The data show that, for the called-for reduction in toxicity, 41.5, 30.0, and 11.5 mg/l chlorine would be required for contact times of 15, 60, and 180 min, respectively.

Treatment of 0.3 mg/l toxaphene with as much as 200 mg/l chlorine for 180 min showed no reduction in toxaphene toxicity to fish. Toxaphene, as would be expected of a highly chlorinated hydrocarbon, is completely inert to additional treatment with aqueous chlorine solution.

No attempt was made to treat sulfoxide with chlorine, because the 96-hr TL_m value for fish, 0.74 mg/l, is well above the concentration likely to be present in a water treated with any fish poison formulation. For example, treatment of a water with 2 mg/l Formulation C would yield a concentration of 0.05 mg/l sulfoxide.

Commercial fish poison Formulations A, B, C, and D in a concentration of 2 mg/l were also treated with increasing amounts of chlorine for various contact times. The data were then plotted according to Fig. 5 and the curves extrapolated to obtain the amounts of chlorine required to reduce the toxicity to one-half of their 96-hr TL_m value. The close agreement of the values for Formulations B, C, and D (Table 6) indicates the presence of a common toxic agent. These formulations, previously described, depend primarily for their toxicity to fish on rotenone and other extractives obtained from the natural products cube and derris roots. The values for chlorine requirements for 2.0 mg/l of the formulations are roughly comparable to that for 0.1 mg/l of pure rotenone, as the formulations contain approximately 5 per cent rotenone. The observed differences may be explained by

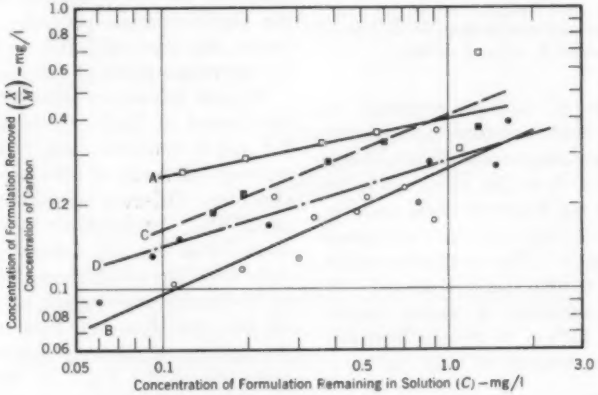


Fig. 3. Carbon Adsorption Isotherms for Commercial Fish Poison Formulations

See Table 4 for initial concentrations and parameters.

TABLE 4

*Initial Concentrations and Parameters for Commercial Fish Poison Formulations**

Formulation	Initial Concentration *mg/l*	Parameters	
		K	$\frac{1}{n}$
A	2.0	0.40	0.20
B	2.0	0.27	0.43
C	2.0	0.41	0.43
D	2.0	0.28	0.29

* Values related to Fig. 3.

variations that may be expected in a commercial formulation and by the fact that, in addition to rotenone, some formulations contain other root extractives and synergists. Derris and cube extractions yield materials less active physiologically to fish than pure rotenone.

Chlorination of Formulation A revealed the presence of both rotenone, which is oxidized by chlorine, and toxaphene, which resists any action by chlorine. Thus, the curves for the chlorination of 1.0 mg/l Formulation A (Fig. 6) demonstrate that toxicity due to the rotenone content can be reduced with about 2–4 mg/l chlorine with a contact time of 180 min, although this solution remains toxic to fish because of the unaffected toxaphene content.

Application of substantial amounts of chlorine offers a means for removing the toxicity of some commercial fish poison formulations, particularly those containing only rotenone or rotenoid compounds as the active ingredient. Formulations that include other toxic agents—such as Formulation A, which contains 7 per cent toxaphene—are resistant to any amount of chlorine application and may be removed from solution only by activated carbon. Because a large excess of chlorine is required to detoxify rotenone, some means must be provided for dechlorination before the water may be distributed to the consumer.

TABLE 5

Effectiveness of Chlorine Treatment of 0.1 mg/l Rotenone Solution

Contact Time—*min*					
15		60		180	
Chlorine Applied *mg/l*	Rotenone Residual *mg/l*	Chlorine Applied *mg/l*	Rotenone Residual *mg/l*	Chlorine Applied *mg/l*	Rotenone Residual *mg/l*
4.3	0.09	1.5	0.07	0.73	0.085
10.5	0.064	7.4	0.06	1.5	0.07
17.5	0.058	14.8	0.02	2.2	0.06
21.0	0.042	22.1	0.01	4.4	0.04
24.5	0.023	29.5	<0.005	7.3	0.013
31.6	0.012	44.3	<0.005	11.0	0.005
38.5	<0.005			18.3	<0.005
56.1	<0.005			21.9	<0.005

TABLE 6

Amounts of Chlorine Required to Reduce 2.0 mg/l of Fish Poison Formulations and 0.1 mg/l Rotenone to One-Half of 96-hr TL_m

Contact Time *min*	Formulation B	Formulation C	Formulation D	Rotenone
	Chlorine Required—*mg/l*			
15	32	34	38	41.5
60	21	20	21	30
180	15	12	10	11.5

Chlorine Dioxide Treatment

Chlorine dioxide is a powerful oxidizing agent and has been found effective in controlling some taste and odor problems. On a weight basis, expressed in terms of available chlorine, chlorine dioxide has, theoretically, 2.5 times as much oxidizing capacity as chlorine. As rotenoid compounds

are particularly sensitive to oxidation, use of chlorine dioxide for this purpose appeared to offer a promising method of treatment.

A 0.1 mg/l solution of rotenone was prepared in water free of chlorine dioxide demand and then treated with varying amounts of chlorine dioxide. The reaction was allowed to proceed for 15, 60, and 180 min at 25°C. After dechlorination with sodium thiosulfate, residual rotenone was determined by bioassay. It is clearly evident from the data (Fig. 7) that chlorine dioxide is an effective oxidant for rotenone. Figure 7 indicates that the amounts of chlorine dioxide which must be applied to a 0.1 mg/l solution of rotenone to reduce the toxicity to one-half the 96-hr TL_m for fish (0.003 mg/l rotenone) range from 0.88 mg/l for a contact time of 15 min to 0.50 mg/l for 180 min. Doses of chlorine dioxide in concentrations as large as 7.9 mg/l had no effect on 0.3 mg/l toxaphene, even after a contact time of 180 min.

Alum Coagulation

Alum coagulation failed to remove either rotenone, toxaphene, or the commercial formulations. Treatment of these compounds with as much as 100 mg/l alum produced no significant reduction in concentration.

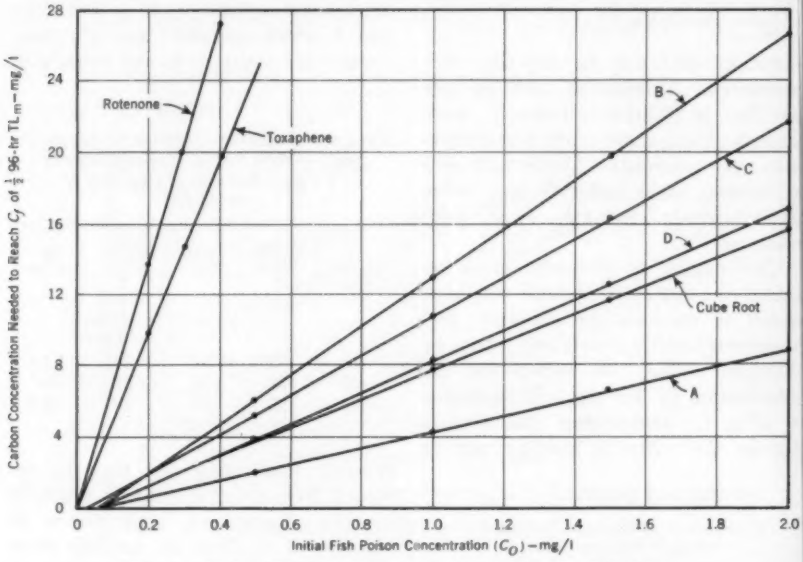


Fig. 4. Carbon Dosage Curves for Removal of Fish Poisons

From these curves, the amounts of carbon required to reduce any concentration of fish poison to the selected permissible residual concentration can be determined.

Stability of Fish Poisons

Knowledge of the stability of the fish poisons is important, because the degree of stability will determine the

required duration of special water treatment. It is obvious that detoxification of the fish poison by natural agencies in a water will permit a reduction in the duration of its treatment.

Rotenone is readily detoxified by the action of light and air, and the rate of decomposition is proportional to the log of the light energy.[17] Subba-Rao and Pollard [18] reported that almost all rotenone toxicity is lost in 5–6 spring days or in 2–3 summer days. In a laboratory experiment, Leonard [8] found that the toxicity of rotenone, added as 1.0 mg/l derris suspension, had dissipated at 60°F in 20–41 hr. He further found that a 1 per cent suspension of powdered derris root in water lost between 60 per cent and 75 per cent of its toxicity in 34 days.

Field observations by Smith [9] showed that 1.33 mg/l derris remained toxic to fish for 1 month, but was nontoxic in 35 days. Twenty-eight days after treating a large lake with 1.8 mg/l of a commercial formulation, Hoffman and Payette [19] were able to restock with fish.

Alkalinity seems to be important to the persistence of rotenone. Clemens and Martin [10] showed that the toxicity of a concentration of 0.3–0.5 mg/l of a 5 per cent rotenone emulsion was lost in 1–3 days in water that had a methyl orange alkalinity of 60–284 mg/l; 3–6 days were required in waters of low alkalinity, such as 16 mg/l. Low temperatures and exclusion of air and light, under ice cover, markedly decrease the rate of rotenone decomposition. A lake, treated with

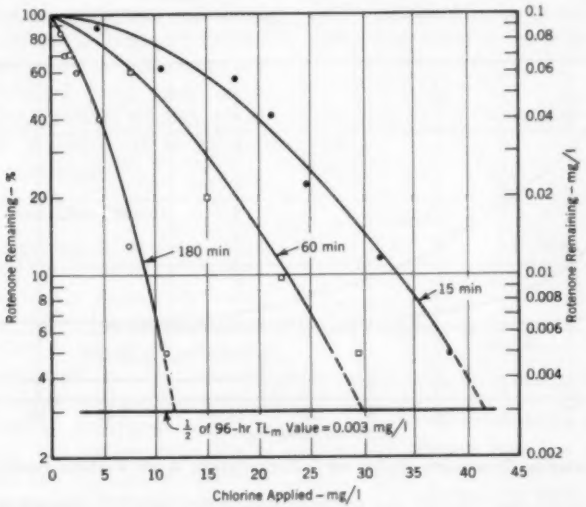


Fig. 5. Effectiveness of Chlorine Treatment of 0.1 mg/l Rotenone Solution

The data in Table 5 have been plotted to provide, by extrapolation, an estimation of the amount of chlorine required to reduce the toxicity of 0.1 mg/l rotenone to one-half the 96-hr TL_m.

a rotenone preparation under such conditions, remained lethal to fish for 5 months.[20] Thus, rotenone is a fairly labile compound whose maximum life in a natural water may be more than 5 months, under conditions adverse for decomposition, but is generally much less than 1 month, under more favorable conditions.

The introduction of toxaphene as a practical fish poison is relatively recent; hence, much less is known about its persistence in natural waters. The reported length of time a water remains toxic after treatment with toxaphene varies, ranging from a minimum of 4 weeks, as reported by Hemphill,[21] to a maximum of more than 2.5 years.[20] Within these extremes, Tanner and Hayes[22] showed that two lakes treated with 0.1 mg/l toxaphene remained toxic for 7 and 10 months. Detoxification of toxaphene was reported by Hooper and Grzenda[23] to depend on exposure to light, dissolved-oxygen content, and temperature. Hard water detoxified more rapidly than soft water, and toxicity reduction was greatly accelerated by water movements that brought the toxicant into contact with the walls and bottom of the aquarium. Rate of detoxification was increased by the presence of solid surfaces, such as sand and mud. Hooper and Grzenda also concluded that microorganisms are capable of detoxifying toxaphene. Under field conditions, toxaphene was found to retain toxicity for long periods. Ten Michigan lakes, after treatment with a fish poison formulation containing toxaphene, remained toxic for 8–33 months; in another field trial, from 2–10 months. Extreme stability of toxaphene in a sandy soil was demonstrated by Hetrick,[24] who found that toxaphene retained its toxicity to termites after 10 years in sandy soil.

From the limited experience with the stability of toxaphene in water, it

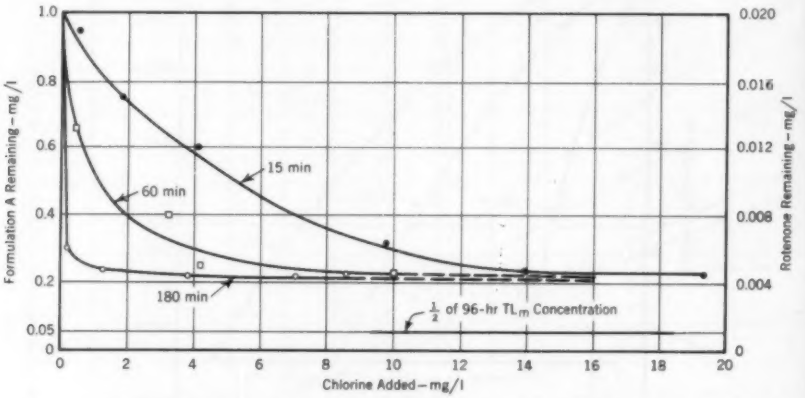


Fig. 6. Chlorine Treatment of 1.0 mg/l Formulation A at Various Contact Times

The curves show that toxicity due to the rotenone content of Formulation A can be reduced to nontoxic levels with 2–4 mg/l chlorine with a contact time of 180 min. The solution, however, remains toxic to fish because of the unaffected toxaphene content.

seems clear that toxicity of toxaphene will persist much longer than that of rotenone, perhaps for as long as 33 months.

Odor Problems

In addition to the problem of removing toxicity, the water treatment plant may have to contend with removal of odors associated with the use of a fish poison formulation containing hydrocarbon solvents. Toxaphene is a very odorous compound and would certainly have to be removed for this reason alone, if not for reasons of toxicity. A detailed study made of the odor problems related to fish poison formulations in water will be reported in a subsequent paper.[25]

Summary and Discussion

Fish management of a water supply reservoir by application of chemical agents toxic to fish appears to be consistent with the objective of a water treatment plant—namely, to produce a safe and potable water. The inescapable criteria of safe and potable finished water following treatment may be achieved by: (1) proper selection of a fish poison and (2) use of the most effective treatment process, coupled with close control of quality. Although both rotenone and toxaphene are relatively toxic, and their routine use in water supplies would be regarded with disfavor, their occasional use for fish management should present no hazard if adequate measures are taken for their removal by treatment or by decomposition through natural processes.

The doses of chemicals required to produce satisfactory finished water in the laboratory investigations are shown in Table 7. In all of these data, good water quality was presumed to be attained when the concentration of toxic components of a fish poison had been reduced or altered to a value of one-half its 96-hr TL_m, as shown in Table 1. The chemical doses shown represent the amounts determined under laboratory conditions and are useful only for comparative purposes. The amount of treatment chemical required under practical conditions, which are special to any water plant and water quality, cannot be predicted from these laboratory data. The data, however, can be considered useful for predicting the treatment most likely to produce a safe finished water.

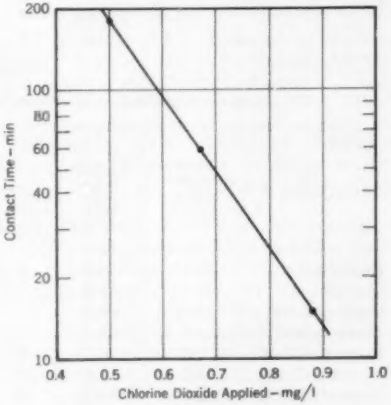


Fig. 7. Contact Time and Chlorine Dioxide Required to Detoxify 0.1 mg/l Rotenone

The temperature of the solution was 25°C; the pH, 7.5.

Selection of fish poison. On the basis of ease of removal of the compounds studied, the logical choice of the most suitable fish poison is pure rotenone. This chemical is easily removed by moderate amounts of activated carbon and by reasonable amounts of chlorine when 3 hr of contact time are

available. The necessity to dechlorinate, however, is one point against this method of treatment. Treatment with chlorine dioxide offers another means for rotenone detoxification. The rapid disappearance of rotenone in the reservoir from natural causes insures a relatively short critical period at the water treatment plant.

Cube powder and any of the formulations that contain only rotenone or rotenoid materials would be a desirable fish poison. The amounts of treatment chemicals required for these are somewhat greater than those required for pure rotenone, because the formulations contain, in addition to rotenone, rotenoid extractives and such synergists as sulfoxide and emulsifiers, all of which add to the problems of removal.

The use of toxaphene or formulations containing toxaphene would necessitate the removal of practically all the toxaphene at the water plant, because no natural dissipation in the reservoir can be expected in a reasonable time. Treatment with activated carbon would have to be continuous at a sustained high level, in view of toxaphene persistence, until the entire contents of the reservoir had gone through the plant or until dilution with uncontaminated water had reduced the concentration: No common treatment other than that with activated carbon will remove toxaphene; both chlorine and alum coagulation are completely ineffective.

Selection of treatment process. The single most effective water treatment process for removing fish poisons from a water supply is unquestionably the treatment with activated carbon. Activated carbon will remove not only rotenone and toxaphene poisons but also the solvents and emulsifiers present in all the commercial formulations. This broad activity also eliminates odors, which will be discussed in a subsequent paper.[25]

Chlorine and chlorine dioxide are effective against rotenone and rotenoid compounds, but some means must be

TABLE 7

Summary of Data on Treatment of Water Containing Fish Poisons

Fish Poison	Initial Concentration of Poison *mg/l*	Carbon Treatment* *mg/l*	Contact Time—*min*			Chlorine Dioxide Treatment* *mg/l*	Estimated Comparative Stability†
			15	60	180		
			Chlorine Treatment*—*mg/l*				
Rotenone	0.1	6.6	41.5	30	11.5	0.88–0.50	1 month
Toxaphene	0.1	5.0	—‡	—‡	—‡	—‡	1 year
Cube powder	2.0§	9.8					1 month
Formulation A	2.0	8.8	—‡	—‡	—‡		1 year
Formulation B	2.0	26.4	32	21	15		1 month
Formulation C	2.0	21.6	34	20	12		1 month
Formulation D	2.0	16.7	38	21	10		1 month

* Concentration of reagent required to reduce fish poisons to one-half of 96-hr TL_m value.
† See discussion on stability for reported data.
‡ Not effective in removing poison. Alum treatment was not effective in removing any of the poisons studied.
§ Containing 5 per cent rotenone. This is equivalent to 0.1 mg/l rotenone, although other toxic rotenoid compounds are also present.

What must be

provided for removing the substantial amount of residual chlorine. Chlorination, however, has practically no effect on the other materials in fish poison formulations. Hence, recourse to activated carbon must be made to eliminate the odors due to these materials. Alum coagulation has proved to be completely ineffective in removing fish poisons from water.

Acknowledgments

The authors wish to thank G. A. Rourke, chemist, formerly of Taft Center, and Quentin Pickering, biologist, Water Supply & Water Pollution Research Branch of Taft Center, for their assistance in the laboratory work. Thanks are also expressed to Herbert E. Stokinger, chief of Toxicologic Services, Occupational Health Field Headquarters of Taft Center, for contributing the section on toxicity of rotenone.

References

1. AWWA Statement of Policy. Recreational Use of Domestic Water Supply Reservoirs. *Jour. AWWA*, 50:579 (May 1958).
2. Ball, R. C. A Summary of Experiments in Michigan Lakes on the Elimination of Fish Populations With Rotenone, 1934–42. *Trans. Am. Fisheries Soc.*, 75:139 (1948).
3. Haag, H. B. Toxicological Studies on Derris Elliptica and Its Constituents: I. Rotenone. *J. Pharmacol. Exp. Therap.*, 43:193 (1931).
4. Haag, H. B. Studies of Human Subjects and Animals of Rotenone-Bearing Products. *Soap Chem. Specialties*, 13:112c (1937).
5. Lehman, A. Chemicals in Foods: A Report to the Association of Food and Drug Officials on Current Developments. Part II. Pesticides. *Assn. Food & Drug Officials US, Quart. Bul.*, 15:122 (1951).
6. Lehman, A. Chemicals in Foods: A Report to the Association of Food and Drug Officials on Current Developments. Part II. Pesticides. *Assn. Food & Drug Officials US, Quart. Bul.*, 16:47 (1952).
7. *Toxaphene Manual*—Toxicology. Hercules Powder Co., Wilmington, Del. (1955).
8. Leonard, J. W. Notes on the Use of Derris as a Fish Poison. *Trans. Am. Fisheries Soc.*, 68:269 (1939).
9. Smith, N. W. Copper Sulfate and Rotenone as Fish Poisons. *Trans. Am. Fisheries Soc.*, 69:141 (1940).
10. Clemens, H. P. & Martin, Mayo. Effectiveness of Rotenone in Pond Reclamation. *Trans. Am. Fisheries Soc.*, 82:166 (1953).
11. Yun-Pei-Sun. Bioassay of Pesticide Residues. *In* R. L. Metcalf, *Advances in Pest Control Research*. Interscience Publishers, New York (1957). vol. 1.
12. Dewey, J. E. Utility of Bioassay in the Determination of Pesticide Residues. *J. Agr. Food Chem.*, 6:274 (1958).
13. Tarzwell, C. M. & Henderson, C. Toxicity of Dieldrin to Fish. *Trans. Am. Fisheries Soc.*, 86:245 (1956).
14. Doudoroff, P. S., et al. Bioassay Methods for the Evaluation of Acute Toxicity of Industrial Wastes to Fish. *J. WPCF*, 23:1380 (1951).
15. Jones, H. A. & Smith, C. M. The Solubility of Rotenone. I. Solubility and Optical Rotation in Certain Organic Solvents at 20°. *J. Am. Chem. Soc.*, 52:2554 (1930).
16. Lawrence, J. M. Preliminary Results on the Use of Potassium Permanganate to Counteract the Effects of Rotenone on Fish. *Progressive Fish Culturist*, 18:15 (1956).
17. Metcalf, R. L. *Organic Insecticides*. Interscience Publishers, New York (1955).
18. Subba-Rao & Pollard, A. Photodecomposition of Rotenone in Spray Deposits. III. Kinetics of the Photodecomposition. *J. Sci. Food Agr.*, 2:462 (1951).
19. Hoffman, D. A. & Payette, R. E. Operation Carp on a San Diego Reservoir. *Wtr. & Sew. Wks.*, 103:281 (1956).
20. Stroud, R. H. & Seaman, E. A. Field Conservation Highlights of 1956.

Sport Fisheries Institute, Washington, D.C. (1957).
21. HEMPHILL, J. E. Toxaphene as a Fish Toxin. *Progressive Fish Culturist*, 16:41 (1954).
22. TANNER, H. A. & HAYES, M. L. Evaluation of Toxaphene as a Fish Poison. Colorado Cooperative Fishery Research Unit. Quart. Rpt., 1:31 (1955).
23. HOOPER, F. F. & GRZENDA, A. R. The Use of Toxaphene as a Fish Poison. *Trans. Am. Fisheries Soc.*, 85:180 (1955).
24. HETRICK, L. A. Ten Years of Testing Organic Insecticides as Soil Poisons Against the Eastern Subterranean Termite. *J. Econ. Entomol.*, 50:316 (1957).
25. COHEN, J. M.; ROURKE, G. A.; & WOODWARD, R. L. Effect of Fish Poisons on Water Supplies: Part 2. Odor Problems. *Jour. AWWA (in press)*.

Binding the Year's Journals

Arrangements have been made by AWWA for members and subscribers to have their JOURNALS bound into distinctively designed volumes, with the JOURNAL masthead, AWWA seal, volume number, and year stamped in gold on the spine.

The price for such a binding, using the best grade of indigo blue washable buckram, and with your name imprinted on the front cover, is $4.65. (This price is for binding into one volume the text sections of the twelve issues, January through December, including the table of contents and text indexes for the year—from the December issue—but omitting the advertising sections and paper covers.)

Ship your journals parcel post, together with full remittance (check or money order) and address to which bound volume should be sent, to:

Publishers' Authorized Bindery Service, Inc.
430 W. Erie St.
Chicago 10, Ill.

Before you ship, check for missing issues and check each issue for defects, missing pages, etc. Pack carefully so that nothing is crumpled or torn. The bindery will forward the bound volume within 30 days of receipt and will ship prepaid anywhere in the United States.

A microfilm addition of the JOURNAL is available to regular subscribers from University Microfilms, 313 N. First St., Ann Arbor, Mich. The cost of the microfilm edition of the 1959 volume was $9.60.

Determination of Ferrous Iron in the Presence of Ferric Iron With Bathophenanthroline

G. Fred Lee and Werner Stumm

A contribution to the Journal by G. Fred Lee, Asst. Prof., Graduate School of Public Health, Univ. of Pittsburgh, Pittsburgh, Pa., and Werner Stumm, Asst. Prof., Dept. of San. Eng., Harvard Univ., Cambridge, Mass. The investigation was supported by USPHS Grant RG-5831.

ACCORDING to the tenth edition of *Standard Methods*,[1] "Probably no chemical determination involves more uncertainty than that of iron." Although the colorimetric methods applicable to natural waters are relatively satisfactory for the determination of total iron, difficulties may be encountered in the specific determination of ferrous iron. The analytic method recommended for the specific determination of ferrous iron in the ninth edition of *Standard Methods*[2] and referred to in the tenth edition * has been found, as part of a quantitative investigation on the kinetics of ferrous iron oxidation by dissolved oxygen, to lack specificity for the determination of trace (less than 1 mg/l) quantities of ferrous iron in the presence of ferric iron.

Some of the difficulties encountered in making an analysis for ferrous iron with the use of the recommended 1,10-phenanthroline method,[1] and a method using bathophenanthroline, 4,7-diphenyl-1,10-phenanthroline for the specific determination of ferrous iron, will be discussed here.

* Authors' comment on the revised phenanthroline method included in the eleventh edition of *Standard Methods*[2a] (which appeared subsequent to the preparation of the present article) will be published in the "Notes and Comment" section of a forthcoming issue of the JOURNAL.—ED.

1,10-Phenanthroline Method

The 1,10-phenanthroline method for the determination of total iron is based on the reduction of the iron to the ferrous state and its subsequent reaction with 1,10-phenanthroline to form a highly colored stable complex suitable for spectrophotometric analytic procedures.[1] It has been generally assumed that ferrous iron may be determined by merely omitting the reducing agent in the 1,10-phenanthroline procedure for the determination of total iron.[1,2] Harvey, Smart, and Amis[3] reported that ferrous iron and the total iron concentration can be determined on a single sample by measurement of the absorbance of the ferrous- and ferric-1,10-phenanthroline complexes at two different wavelengths. But investigations by the present authors have shown that both the procedure in *Standard Methods* and that by Harvey and associates are applicable only under certain conditions. The conditions necessary to obtain reliable results are: (1) 1 mg/l or more of ferrous iron must be present in the solution being analyzed, (2) the molar ratio of 1,10-phenanthroline to total iron (ferrous plus ferric) must exceed 30, (3) the absorbance measurements must be made within 10–15 min after color forma-

tion, and (4) the solution must be free of interfering materials and protected from direct sunlight.

When the sample contains less than approximately 1 mg/l ferrous iron in the presence of ferric iron, the color formed is unstable and increases with time. For example, a 40–60 per cent increase in absorbance was observed for various ferrous-ferric mixtures in a period of 30 min. The increase in color with time is the result of the reduction of trivalent iron to ferrous-1,10-phenanthroline. This reduction can be attributed to the larger stability constant of ferrous-1,10-phenanthroline complex, as compared to the ferric-1,10-phenanthroline complex.[4,5] The mechanism of this reduction is under investigation.

The second condition of a 30-fold molar excess of 1,10-phenanthroline to the total iron must be met to obtain stable color development in the optimum range for this procedure. If a ratio of less magnitude is used, the developed color changes rapidly with time. The large excess is based on total iron, as both ferrous and ferric iron form complexes with 1,10-phenanthroline.

In addition to the formation of complexes with bivalent and trivalent iron, phenanthroline forms complexes with many other metals. Smith and Richter[6] reported that the bivalent ions of cadmium, copper, zinc, nickel, chromium, and ruthenium also form complexes with phenanthrolines. These metals form either colored or noncolored complexes dependent on the particular metal. Because phenanthroline is a base, it combines with a proton to form phenanthrolium ion; therefore, the amount of excess phenanthroline necessary is dependent on pH. At a pH of less than approximately 5, the protons in solution compete with the iron for the available positions on the nitrogen atoms of 1,10-phenanthroline. Therefore, the amount of excess phenanthroline is dependent on the acidity of color formation, particularly at pH values less than 4–5.

It should be pointed out that in the determination of the total iron content of industrial wastes, which contain a large concentration of other metals, a larger than normal excess of 1,10-phenanthroline may be needed to overcome the amount of 1,10-phenanthroline complexed by other metals; otherwise low readings may be obtained because of an insufficient excess of 1,10-phenanthroline.[7,8] Even under the optimum condition, the color developed from ferrous-1,10-phenanthroline is not stable over long periods of time. The color developed under the optimum condition from a mixed ferrous-ferric solution increases especially rapidly with time if the sample is allowed to stand in direct sunlight.

Because the 1,10-phenanthroline method for the determination of ferrous iron was not generally applicable to the conditions that would be encountered in the authors' investigation of the kinetics of oxygenation of ferrous iron, and to those conditions that may be encountered in the analysis of the ferrous iron content of surface and ground waters, it was necessary to review the analytic methods that are reported to be specific for ferrous iron.

Previously Reported Methods

Numerous volumetric titration procedures using oxidizing agents (MnO_4^-, $Cr_2O_7^{--}$, Ce^{4+}) have proved to be of value for the determination of relatively large quantities of ferrous iron in the absence of other reducing agents.

These methods, however, are not applicable to the determination of ferrous iron at the low concentration generally found in natural waters.[9]

Another procedure that is used for analytic differentiation of ferrous iron from ferric iron is polarography.[10] But as with the volumetric titration procedures, polarography is limited to use with relatively large concentrations of ferrous iron, compared to those normally found in surface waters. The coulometric titration procedure described by Cooke and associates[11] is an extremely sensitive method for ferrous iron determination, but it requires the use of instrumentation not normally present at water plants.

Because of their sensitivity and ease in performing an analysis, colorimetric procedures have been the most widely used methods for the determination of ferrous iron in natural waters. A variety of color-developing reagents have been used, ranging from thiocyanate, which stabilizes the ferric iron state, to the pyridyls,[12] nitrosophenol,[13] and several derivatives of phenanthroline, all of which stabilize the ferrous iron state to form highly colored compounds.[6] These reagents, however, are capable of disturbing the ferrous-ferric equilibrium. Some difficulties have been reported concerning the use of these reagents for specific ferrous iron determination. For example, Hutchinson[14] reported that the thiocyanate and dipyridyl methods for the determination of ferrous iron in natural waters do not give reliable results. The procedure using nitrosophenol as the color-developing agent is reported to have a greater sensitivity for ferrous iron than do the pyridyls,[13] but this procedure requires rigid control of experimental conditions to obtain reliable results.

Analytic methods using 1,10-phenanthroline or one of its substituted derivatives as the chromatogenic agent have been widely employed for the determination of total iron of natural or treated waters[15]; 1,10-phenanthroline has been suggested for specific determination of ferrous iron.[1, 3] But, as has been previously pointed out, 1,10-phenanthroline has limited applicability for the specific determination of ferrous iron in the presence of ferric iron.

As the 1,10-phenanthroline procedure did not yield reliable results, and as none of the previously reported procedures showed promise for the determination of ferrous iron in solutions with concentrations smaller than 1 mg/l ferrous iron, it was decided to investigate one of the derivatives of 1,10-phenanthroline as the color-developing agent.

Bathophenanthroline Method

Laitinen and Nelson[16] obtained stable solutions of the ferrous-1,10-phenanthroline complex in the presence of ferric iron when methanol was used as the solvent. But this is of little value in determinations of ferrous iron in natural waters. It does, however, provide a clue as to the type of chromogenic agent desired.

Bathophenanthroline—4,7-diphenyl-1,10-phenanthroline—was selected for three reasons: (1) the reagent has increased sensitivity, approximately twice that of 1,10-phenanthroline; (2) the ferrous-bathophenanthroline complex is readily extracted by immiscible solvents—for example, isoamyl alcohol, nitrobenzene, and *n*-hexyl alcohol—which would tend to stabilize the developed colors; and (3) the extraction procedure renders the method less subject to interferences.

Bathophenanthroline was introduced as a colorimetric reagent for total iron by Smith, McCurdy, and Diehl.[17] They point out that this reagent should prove of value for the determination of small quantities of total iron in water supplies because it is more sensitive than the commonly used 1,10-phenanthroline. Knapp[18] recently published a modification of the original procedure of Smith and associates for the determination of 1 μg/l total iron in highly treated water.

The original procedure proposed by Smith and associates[17] for the determination of total iron has been modified in this investigation for the determination of ferrous iron. The modifications include the omission of the reducing agent and some changes in the volume of reagents and in the manner of purifying reagents.

One of the more important modifications concerns the amount of bathophenanthroline added to the samples. It was found that a larger excess of bathophenanthroline is needed to obtain stable colors for the determination of ferrous iron in the presence of ferric iron than was used[19] for the determination of total iron. The concentration of bathophenanthroline used in the suggested method was found suitable for total iron concentrations as large as 10 mg/l.

The procedure included in the suggested method consists of mixing the sample buffered at pH 4 with bathophenanthroline. The red ferrous-bathophenanthroline complex is extracted with *n*-hexyl alcohol, and the absorbance is determined spectrophotometrically. The *n*-hexyl alcohol, rather than isoamyl alcohol, was used as the immiscible solvent because much cleaner separations were obtained with it.

Results and Discussion

Typical absorbances for a series of ferrous iron and ferric iron solutions are shown in Table 1. These values were obtained with the procedure in the suggested method by using a spectrophotometer * at a wavelength of 533 mμ and a light path of 5.0 cm.

TABLE 1

Absorbance Values for Ferrous and Ferric Solutions

Concentration of Ferrous Iron per 50 ml of Solvent μg	Absorbance	Concentration of Ferric Iron per 50 ml of Solvent μg	Absorbance
2.65	0.112	10	0.021
5.30	0.224	20	0.032
10.6	0.454	30	0.040
15.9	0.694	40	0.048
21.2	0.935	50	0.057

It is of interest to compare the absorbance of ferrous iron with that of ferric iron. Examination of the values in Table 1 shows that ferric iron forms only slightly colored complexes with bathophenanthroline, and that unless large quantities of ferric iron are present its contribution to the absorbance can be neglected. A correction for large amounts of ferric iron can be made by establishing a calibration curve for ferric iron, as described in the procedure of the method, and obtaining the absorbance of aliquots of the sample run with and without hydroxylamine.

A series of eight runs was made, in which 11.70 μg ferrous iron was added to the separatory funnel. A mean iron concentration of 11.62 μg

* Model DU, made by Beckman Instruments, Fullerton, Calif.

was recovered with 10.8–12.1 μg ferrous iron. This procedure has been used successfully for the analysis of ferrous iron remaining as a function of time in an investigation of the kinetics of the oxidation of ferrous iron by oxygen.

One of the problems associated with the use of bathophenanthroline is its cost—$15 per gram in 1-gram lots,[19] or about 8 cents per analysis. Booth and Evett [20] suggested a procedure for the recovery of bathophenanthroline.

Summary

Many of the analytic procedures used for the determination of ferrous iron in the presence of ferric iron are not applicable to the determination of ferrous iron in natural waters because of a lack of sensitivity or because of the instability of developed color. The 1,10-phenanthroline method for the determination of ferrous iron, recommended in the ninth and tenth editions of *Standard Methods*, is likely to result in incorrect results unless it is applied in a very limited range and under special conditions.

A colorimetric procedure using bathophenanthroline as the color-developing reagent has been found to give reliable determinations of ferrous iron in the presence of ferric iron in quantities measured in micrograms.

Acknowledgment

Special thanks are given to Carol Sinclair and Neville Graham, both research assistants at Harvard University, for performing the analysis.

Suggested Procedure for the Specific Determination of Ferrous Iron

The method described here is a modification of a method recommended in two publications of the G. Frederick Smith Chemical Co., Columbus, Ohio.[19, 21]

1. General Discussion

None of the common anions—chloride, nitrate, acetate, or sulfate—interfere in the determination of iron with bathophenanthroline, nor do the alkali and alkaline-earth cations interfere. Large concentrations of perchlorate may cause precipitation of bathophenanthroline. Cobalt forms a light-yellow color with bathophenanthroline, but the color is not extracted from the aqueous solution. Copper forms a yellow complex with bathophenanthroline in neutral and alkaline solutions. At pH 4, the colored copper complex is not formed; thus copper does not interfere.

2. Reagents

2.1. *Bathophenanthroline,* 0.001*M* solution.* Prepare a 50 per cent ethyl alcohol solution of bathophenanthroline by dissolving 0.0332 g 4,7-diphenyl-1,10-phenanthroline ($C_{24}H_{16}N_2$, mol wt 332) in 50 ml of ethyl alcohol and diluting with 50 ml of iron-free water. Store this solution in a glass-stoppered reagent bottle.

2.2. *Hydroxylamine hydrochloride,* 10 per cent, iron-free solution. Reagent grade hydroxylamine often con-

* Solutions of bathophenanthroline and of the other reagents used in this analysis were made by G. Frederick Smith Chemical Co. The solutions are iron-free and ready for use.

tains appreciable amounts of iron. Dissolve 10 g hydroxylamine hydrochloride in 100 ml of distilled water in a 125-ml separatory funnel. Add 2 ml 0.001*M* bathophenanthroline and 10 ml *n*-hexyl alcohol, and extract. Repeat the extraction to insure complete removal of iron. Store the iron-free hydroxylamine hydrochloride solution in a glass-stoppered reagent bottle. This solution has a pH of 1.5–1.75. The small amount of *n*-hexyl alcohol left in the solution is not detrimental.

2.3. *Sodium acetate,* 10 per cent, iron-free solution. Dissolve 10 g sodium acetate in 100 ml of distilled water in a 125-ml separatory funnel. Add 2 ml 0.001*M* bathophenanthroline, and mix well. Add 10 ml *n*-hexyl alcohol, and shake vigorously. Allow the liquids to separate, and draw off the lower aqueous layer into a second separatory funnel. Repeat the separation to insure complete removal of iron. Store the solution in a glass-stoppered reagent bottle.

2.4. n-*Hexyl alcohol.* Reagent grade *n*-hexyl alcohol may be used without further purification. Technical-grade material must be distilled before use.

2.5. *Ethyl alcohol,* 95 per cent. Redistill commercial grade ethyl alcohol to remove iron.

2.6. *Standard iron solutions,* 10 μg/l and 1.0 μg/l Fe. Accurately weigh 0.0702 g ferrous ammonium sulfate hexahydrate (Mohr's salt), dissolve in distilled water that contains 2.5 ml concentrated H_2SO_4, and dilute to 1.0 liter. This solution contains 10 μg/ml Fe. Dilute 10 ml of this solution to 100 ml with distilled water that contains 2.5 ml concentrated H_2SO_4 per liter. This solution contains 1.0 μg/l Fe.

2.7. *Standard ferric iron solution* 10 μg/ml Fe. Add excess aqueous chlorine to an aliquot of 10 μg/m standard ferrous iron solution. Boi to remove unreacted aqueous chlorine Dilute the cool solution to origina aliquot volume.

3. Procedure

3.1. To obtain a sufficient quantity of the water sample, rinse the sample bottle several times with the water, fill the bottle completely full, and stopper in such a manner that no air bubble is left above the water. Add 2 ml of concentrated HCl per liter of sample. Avoid exposure of sample to atmospheric oxygen in the absence of strong acid.

3.2. Carry several solutions through the process together—for example, two samples of the unknown to be analyzed, three or four standards, and a blank. Once a calibration curve has been established, further standards need not be run except as an occasional check.

3.3. The determination of ferrous iron in natural waters requires boiling of the sample in the presence of a strong acid to free the iron from organic matter or from mixed ferrous-ferric oxides. This can usually be accomplished by adding 1 ml of concentrated iron-free HCl per 25 ml of sample and boiling for approximately 5 min. A weak base such as sodium acetate should be used to neutralize the excess acid.

3.4. For the standards, use various amounts of the second standard iron solution (1 μg/ml)—for example: 2.0, 4.0, 6.0, 8.0, 10.0, 12.0 . . . and 20 ml, corresponding to 2.00, 4.00 . . . and 20.0 μg of iron. The volumes of reagents are based on a 5-cm light

ath. Appropriate modifications can e made for other cell lengths by varying the concentrations of the iron in he reference solutions.

3.5. Pipet the sample (water being ested or standard iron solution) into 125-ml separatory funnel. The pH hould be less than 1.5. If the sample aken was less than 10 ml, add sufficient distilled water to bring the volume to 10 ml. Larger volumes may e used. Use 10 ml of distilled water or the blank.

3.6. To each sample, add 4 ml of 10 per cent sodium acetate solution. The olution at this point should be pH 4. f the original sample of the water was acidified with HCl when taken, dd an additional 4 ml of sodium cetate solution. Add 2 ml of hydroxylamine hydrochloride solution to standard iron solutions. (Omit the ydroxylamine in waters being tested or ferrous iron and in the ferric iron standards.)

3.7. Add 15 ml 0.001*M* bathophenanthroline, and mix. Add 10.0 ml *n*-hexyl alcohol, stopper the funnel, and shake the mixture thoroughly. Allow the liquids to separate for at least 5 min after shaking.

3.8. After the liquids have cleanly separated into two layers, draw off and discard the lower aqueous layer. Shake away any of the aqueous layer remaining in the stem of the separatory funnel. Drain the *n*-hexyl alcohol layer into a 50-ml volumetric flask—a smaller-volume flask may be used to increase the sensitivity—and wash out the separatory funnel with 2–3 ml of ethyl alcohol added from a pipet. This should be done in such a manner that the upper stopper of the funnel and the walls of the funnel are uniformly washed at least twice by a film of alcohol as it drains from the top to the bottom. Transfer this wash alcohol to the volumetric flask. Dilute the solution in the flask to the mark with ethyl alcohol, and mix by shaking. At this point the solution in the volumetric flask should be clear, with no turbidity.

3.9. Determine the absorbance of the solution within 10 min. Avoid exposure of solution to strong sunlight, making the measurement at a wavelength of 533 mμ. The iron-bathophenanthroline color conforms to Beer's law, so that a plot of absorbance (negative logarithm of transmittance) against concentration of iron yields a straight line with the slope equal to the absorptivity.

If the blank turns out to be large, owing to iron in the distilled water or reagents, it may be necessary to repeat the work using water or reagents that have been freed of iron in the same manner as the sodium acetate solution. The procedure described can be used for the determination of total iron by addition of 2 ml of hydroxylamine hydrochloride to the iron samples prior to the addition of bathophenanthroline.

References

1. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955). p. 125.
2. *Standard Methods for the Examination of Water and Sewage.* APHA & AWWA, New York (9th ed., 1946).
2a. *Standard Methods for the Examination of Water and Wastewater.* APHA, AWWA & WPCF, New York (11th ed., 1960).
3. Harvey, A. E.; Smart, J. A. & Amis, E. S. Simultaneous Spectrophotometric Determination of Iron (II) and Total Iron With 1,10-Phenanthroline. *Anal. Chem.*, 27:26 (1955).

4. KOLTHOFF, I. M.; LEE, T. S.; & LEUSSING, D. L. Equilibrium and Kinetic Studies on the Formation and Dissociation of Ferroin and Ferrin. *Anal. Chem.*, 20:985 (1948).
5. LEE, T. S.; KOLTHOFF, I. M.; & LEUSSING, D. L. Reaction of Ferrous and Ferric Iron With 1,10-Phenanthroline. I. Dissociation Constant of Ferrous and Ferric Phenanthrolines. *J. ACS*, 70:2348 (1948); II. Kinetics of Formation and Dissociation of Ferrous Phenanthrolines. *J. ACS*, 70:3596 (1948).
6. SMITH, G. F. & RICHTER, F. P. *Phenanthroline and Substituted Phenanthroline Indicators.* G. Frederick Smith Chemical Co., Columbus, Ohio (1944).
7. FORTUNE, W. B. & MELLON, M. G. Determination of Iron With *o*-Phenanthroline. *Ind. Eng. Chem. Anal. Ed.*, 10:60 (1938).
8. MORRIS, R. L. Determination of Iron in Water in the Presence of Heavy Metals. *Anal. Chem.*, 24:1376 (1952).
9. KOLTHOFF, I. M. & BELCHER, R. *Volumetric Analysis.* Interscience Publishers, New York (1957). vol. 3.
10. KOLTHOFF, I. M. & LINGANE, J. J. *Polarography.* Interscience Publishers, New York (2nd ed., 1952). vol 2.
11. COOKE, W. D.; REILLEY, C. N.; & FURMAN, N. H. Sensitive End-Point Procedure for Coulometric Titrations. *Anal. Chem.*, 23:1662 (1951).
12. MOSS, M. L. & MELLON, M. G. Colorimetric Determination of Iron With 2,2-Bipyridyl and With 2,2,2″-Terpyridyl. *Ind. Eng. Chem. Anal Ed* 14:862 (1952).
13. CRONHEIM, G. & WINK, W. Determination of Divalent Iron. *Ind. Eng. Chem. Anal. Ed.*, 14:447 (1947).
14. HUTCHINSON, G. E. *A Treatise on Limnology.* John Wiley & Sons, New York (1957). vol. 1.
15. CALDWELL, D. H. & ADAMS, R. B. Colorimetric Determination of Iron in Water With *o*-Phenanthroline. *Jour. AWWA*, 38:727 (Jun. 1946).
16. LAITINEN, H. A. & NELSON, J. S. Determination of Hydroperoxides in Rubber and Synthetic Polymers. *Ind. Eng. Chem. Anal. Ed.*, 18:422 (1946).
17. SMITH, G. F.; MCCURDY, W. H.; & DIEHL, H. The Colorimetric Determination of Iron in Raw and Treated Municipal Water Supplies by Use of 4,7-Diphenyl-1, 10-Phenanthroline. *Analyst*, 77:418 (1952).
18. KNAPP, W. G. Modified 4,7-Diphenyl-1, 10-Phenanthroline Method Sensitive to 1 ppb of Iron in High Purity Water. *Anal. Chem.*, 31:1445 (1959).
19. *Colorimetric Determination of Iron in Raw and Treated Water, Using Bathophenanthroline.* G. Frederick Smith Chemical Co., Columbus, Ohio (1958).
20. BOOTH, E. & EVETT, T. W. The Absorptiometric Determination of Traces of Iron in Bismuth. *Analyst*, 83:80 (1958).
21. DIEHL, H. & SMITH, G. F. *The Iron Reagents*—Bathophenanthroline, 2,4,6-Tripydyl-S-Triazine, and Phenyl-2-Pyridylketoxime. G. Frederick Smith Chemical Co., Columbus, Ohio (1960).

Suggested Amperometric Titration Method for Determining Dissolved Oxygen

Eugene Goldman and Bernard Dietz

A contribution to the Journal by Eugene Goldman, Chemist, and Bernard Dietz, Student Engr., both of the San. Eng. Div., Dept. of Water & Power, Los Angeles, Calif.

AMPEROMETRIC titration is a popular method for the determination of free and total chlorine in water. The method, replacing the usual starch iodine titration, has been successfully used to titrate sulfide.[1]

General Discussion

1.1. *Principle.* As the Winkler method for determining dissolved oxygen is ultimately a starch-iodine titration, the amperometric titrator can also be used for dissolved-oxygen determination.[2] The iodine formed in the Winkler method can be titrated as in the chlorine or sulfide methods, with the use of the same titrant, phenylarsenoxide.

1.2. *Advantages.* The amperometric method is as rapid as the usual Winkler titration and eliminates the troublesome, less-sensitive starch indicator endpoint. The endpoint for the amperometric method is more positive because it is a meter measurement of current rather than a fading color.

1.3. *Disadvantages.* Both methods have the disadvantage that the iodine in solution tends to volatilize at temperature higher than 25°C; therefore, it is best to titrate the samples immediately or, if necessary, to store them at 20°C or lower temperatures. The standard deviation of a number of different samples by the amperometric method averaged ±0.1 in the range of 1.5–8.0 ppm.

2. Apparatus

*Amperometric titrator.** The authors suggest that the titrator be modified for better performance in all types of titration by soldering the cell in place. This improves the connection and prevents drift. The modification has been suggested to the manufacturer. Many water analysts now use the amperometric titrator for chlorine determination in the field, with the use of the automobile electrical system as a power source.

3. Reagents

3.1. *Manganous sulfate solution.* Dissolve 480 g $MnSO_4 \cdot 4H_2O$ in distilled water, filter, and dilute to 1 liter.

3.2. *Alkaline-iodide reagent.* Dissolve 700 g KOH and 150 g KI in distilled water, and dilute to 1 liter.

3.3. *Concentrated sulfuric acid, 36N.*

3.4. *pH 4 buffer.* Dissolve 480 g glacial acetic acid and 243 g $NaC_2H_3O_2 \cdot 3H_2O$ in 400 ml of distilled water, and dilute to 1 liter.

3.5. *Phenylarsenoxide solution, 0.00564N.* Dissolve approximately 0.8 g C_6H_5AsO powder in 150 ml 0.3*N*

* Such as that made by Wallace & Tiernan Inc., Belleville, N.J.

NaOH. After the solution settles, decant 110 ml of this solution into 800 ml of distilled water, and mix thoroughly. Bring the solution to pH 6–7 with dilute HCl solution, and finally dilute to 1 liter. Titrate with freshly standardized iodine solution using starch indicator, and finally adjust with distilled water to 0.00564*N*.

4. Procedure

4.1. To the bottle containing 300 ml of sample, add 2 ml $MnSO_4$ solution and 2 ml of alkaline-iodide reagent well below the surface of the liquid. Mix well * by inverting.

4.2. After the precipitate has resettled, add 1 ml of concentrated H_2SO_4. Mix well by inverting until all the precipitate dissolves. If it does not dissolve in 5 min, add an additional 1 ml of acid.

4.3. Take 10.00 ml of the resulting I_3 solution, add it to the titration jar of the amperometric titrator, and add about 190 ml of distilled water. If the dissolved-oxygen concentration is less than 1.2 ppm, more I_3 solution can be used to increase the sensitivity.

4.4. Add 1 ml of pH 4 buffer.

* The brown precipitate formed by the addition of $MnSO_4$ and alkaline KI to a sample containing dissolved oxygen was air dried and examined by x-ray diffraction. The sample was identified as hausmannite, Mn_3O_4 (actually $MnO \cdot Mn_2O_3$, a structure closely related to magnetite).

4.5. Titrate to the endpoint wit standard phenylarsenoxide, accordir to the instrument-operating instru tions, and record the volume of titra used.

5. Calculation

ppm dissolved oxygen
= mg/l dissolved oxygen
= normality of phenylarsenoxide
× ml phenylarsenoxide

$$\times 8 \times \frac{1{,}000}{\text{ml } I_3 \text{ solution use}}$$

With a 10-ml I_3 solution, an 0.00564*N* phenylarsenoxide, the calcu lation becomes:

ppm dissolved oxygen
= 4.51 × ml phenylarsenoxid

Acknowledgments

The authors wish to thank G. A Uman, of the Los Angeles Departmen of Water & Power, for his x-ray dif fraction analysis, and H. G. Neumann also of the Los Angeles department for his field work on the method.

References

1. Goldman, Eugene. Suggested Amperometric Titration Method for Sulfid Determination. *Jour. AWWA*, 51:93 (Jul. 1959).
2. Ridley, J. E. An Automatic Titrator a Applied to Winkler's Method for Dissolved Oxygen. *Analyst*, 85:508 (1960)

Coliform Group and Fecal Coliform Organisms as Indicators of Pollution in Drinking Water

Paul W. Kabler and Harold F. Clark

A contribution to the Journal by Paul W. Kabler, Chief of Microbiology, and Harold F. Clark, Bacteriologist, both of Water Supply & Water Pollution Research, Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

THE coliform group, as specified in USPHS Drinking Water Standards,[1] is defined in *Standard Methods*[2]: "The coliform group includes all of the aerobic and facultative anaerobic, Gram-negative, nonspore-forming, rod-shaped bacilli which ferment lactose with gas formation within 48 hr at 35°C."

The coliform group includes organisms that differ in biochemical and serologic characteristics and in their natural sources and habitats. *Escherichia coli* is characteristically an inhabitant of human and animal intestines.[3-6] *Aerobacter aerogenes* and *Aerobacter cloacae* are frequently found on various types of vegetation[7-9] and in materials used in joints and valves of pumps and in pipelines.[10, 11] The intermediate-aerogenes-cloacae (I.A.C.) subgroups may be found in fecal discharges, but usually in smaller numbers than *Esch. coli*. *Aer. aerogenes* and intermediate types of organisms are commonly present in soil[12-14] and in waters polluted sometime in the past. Another subgroup comprises plant pathogens[15] and other organisms of indefinite taxonomy about whose habitat information is limited. All the subgroups may be found in sewage and in polluted waters. *Esch. coli* is therefore frequently referred to as "fecal coli"; the I.A.C. group, as "nonfecal." It must be remembered, however, that these terms are only relative.

Survival Times

Available information indicates that organisms of the I.A.C. group tend to survive longer in water than do fecal coliform organisms.[16-18] The I.A.C. group also tends to be somewhat more resistant to chlorination than *Esch. coli* or the commonly occurring bacterial intestinal pathogens.[19-22] Because of these and other reasons, the relative survival times of the coliform subgroups may be useful in distinguishing recent from less recent pollution. In waters recently contaminated with sewage, it is expected that fecal coliform organisms will be present in numbers greater than those of the I.A.C. subgroup. But in waters that have been contaminated for a considerable length of time or have been insufficiently chlorinated, organisms of the I.A.C. subgroup may be more numerous than fecal coliform organisms.

Differentiation of Organisms

Because various members of the coliform group normally grow in diverse natural habitats, attempts have been made to differentiate the population in polluted waters according to their original sources. In his pioneer

work, MacConkey [23, 24] defined the aerogenes group in terms of certain fermentation characteristics, ability to produce indole, and reaction in the Voges-Proskauer test. Rogers, Clark, and Davis,[25] Clark and Lubs,[26] Koser,[27] and others contributed to the development of techniques and laboratory data that differentiated the coliform group on the basis of indole production, methyl red and Voges-Proskauer reactions, and citrate utilization (IMViC tests) into the *Esch. coli*, aerogenes, intermediate, and irregular subgroups. Hajna and Perry [28] and Vaughn, Levine, and Smith [29] further developed the Eijkman [30] test to distinguish organisms of fecal origin from those of nonfecal origin by increased temperature incubation. Clark and associates [31, 32] have reported additional data indicating the usefulness of such tests in sanitary investigations.

Sanitary Significance

Information on the sanitary significance of the various types of coliform organisms is incomplete. In relation to untreated waters, however, the present position may be thus stated:

Fecal coliform organisms (*Esch. coli*) may be considered indicators of recent fecal pollution. No satisfactory method is currently available for differentiating fecal coliform organisms of human and animal origin. Therefore, it is necessary to consider all fecal coliform organisms as indicative of dangerous contamination.

In the absence of fecal coliform organisms, the presence of I.A.C. group organisms in untreated waters may be the result of relatively less recent fecal pollution, soil runoff water, or, infrequently, fecal pollution containing only the I.A.C. group.

In general terms, the presence of fecal coliform organisms indicates recent and possibly dangerous pollution. The presence of I.A.C. organisms suggests less recent pollution or reveals the existence of defects in water treatment or distribution.

Summary

The presence of any type of coliform organism in treated drinking water suggests either inadequate treatment or access of undesirable materials to the water after treatment. Although there are some differences between strain and subgroup organisms with regard to survival under natural conditions and resistance to chlorination, in general all the coliform organisms exhibit survival and resistance patterns in the same order of magnitude. The presence of coliform organisms (as defined earlier) in treated water calls for definitive action for their elimination.

Insofar as bacterial pathogens are concerned, the coliform group is considered a reliable indicator of the adequacy of treatment. As an indicator of pollution in drinking water supply systems, and indirectly as an indication of protection provided, the coliform group is preferred to fecal coliform organisms (*Esch. coli*). Whether these considerations can be extended to include rickettsial and viral organisms has not been definitely determined.

References

1. Drinking Water Standards—1946. *Jour. AWWA*, 38:361 (Mar. 1946); *Pub. Health Repts.*, 61:371 (1946).
2. *Standard Methods for the Examination of Water and Wastewater.*. APHA, AWWA & WPCF, New York (11th ed., 1960).
3. Escherich, T. Intestinal Bacteria in Newborn and Suckling Children. *Fortschr. Med.* (Ger.), 3:515, 547 (1885).
4. Rogers, L. A.; Clark, W. M.; & Evans, A. C. The Characteristics of Bacteria of the Colon Type Found in Bovine Feces. *J. Infectious Diseases*, 15:99 (1915).

5. Parr, L. W. The Occurrence and Succession of Coliform Organisms in Human Feces. *Am. J. Hyg.*, 27:67 (1938).
6. Foote, H. B. The Possible Effects of Wild Animals on the Bacterial Pollution of Water. *Jour. AWWA*, 29:72 (Jan. 1937).
7. Rogers, L. A.; Clark, W. M.; & Evans, A. C. The Characteristics of Bacteria of the Colon Type Occurring on Grains. *J. Infectious Diseases*, 17:137 (1915).
8. Thomas, S. B. & McQuillin, J. Coliaerogenes Bacteria Isolated From Grass. *J. Appl. Bacteriol.*, 15:41 (1952).
9. Thomas, S. B. & Hobson, P. M. Coliaerogenes Bacteria Isolated From Ears and Panicles of Cereal Crops. *J. Appl. Bacteriol.*, 18:1 (1955).
10. Caldwell, E. L. & Parr, L. W. Pump Infection Under Normal Conditions in Controlled Experimental Fields. *Jour. AWWA*, 25:1107 (Aug. 1933).
11. Rapp, W. M. & Weir, P. Cotton Caulking Yarn. *Jour. AWWA*, 26:743 (Jun. 1934).
12. Chen, C. C. & Rettger, L. F. A Correlation Study of the Colon-Aerogenes Group of Bacteria, With Special Reference to the Organisms Occurring in the Soil. *J. Bacteriol.*, 5:253 (1920).
13. Bardsley, D. A. The Distribution and Sanitary Significance of *E. coli*, *B. lactis* Aerogenes, and Intermediate Types of Coliform Bacilli in Water, Soil, Feces, and Ice Cream. *J. Hyg.*, 34:38 (1934).
14. Fran[illegible] N. & Skinner, C. E. Coliaerogenes Bacteria in Soil. *J. Bacteriol.*, 42:143 (1941).
15. Elrod, R. P. The Erwinia-Coliform Relationship. *J. Bacteriol.*, 44:433 (1942).
16. Parr, L. W. Viability of Coli-Aerogenes Organisms in Cultures and in Various Environments. *J. Infectious Diseases*, 60:291 (1937).
17. Platt, A. E. The Viability of *Bact. coli* and *Bact. aerogenes* in Water: A Method for the Rapid Enumeration of These Organisms. *J. Hyg.*, 35:437 (1935).
18. Taylor, C. B. The Ecology and Significance of the Different Types of Coliform Bacteria Found in Water. *J. Hyg.*, 42:23 (1942).
19. Tonney, F. O.; Greer, F. E.; & Danforth, T. F. The Minimal "Chlorine Death Point" of Bacteria. *Am. J. Public Health*, 18:1259 (1928).
20. Heathman, L. S.; Pierce, G. O.; & Kabler, P. W. Resistance of Various Strains of *E. typhi* and Coli-Aerogenes to Chlorine and Chloramine. *Pub. Health Repts.*, 51:1367 (1936).
21. Butterfield, C. T., et al. Influence of pH and Temperature on the Survival of Coliforms and Enteric Pathogens When Exposed to Free Chlorine. *Pub. Health Repts.*, 58: 1837 (1943).
22. Kabler, P. W. Relative Resistance of Coliform Organisms and Enteric Pathogens in the Disinfection of Water With Chlorine. *Jour. AWWA*, 43:553 (Jul. 1951).
23. MacConkey, A. Lactose-Fermenting Bacteria in Feces. *J. Hyg.*, 5:333 (1905).
24. MacConkey, A. Further Observations on the Differentiation of Lactose-Fermenting Bacteria, With Special Reference to Those of Intestinal Origin. *J. Hyg.*, 9:86 (1909).
25. Rogers, L. A.; Clark, W. M.; & Davis, B. J. The Colon Group of Bacteria. *J. Infectious Diseases*, 14:411 (1914).
26. Clark, W. M. & Lubs, W. A. The Differentiation of Bacteria of the Colon-Aerogenes Family by the Use of Indicators. *J. Infectious Diseases*, 17:160 (1915).
27. Koser, S. A. Differential Tests for Colon-Aerogenes Group in Relation to Sanitary Quality of Water. *J. Infectious Diseases*, 35:14 (1924).
28. Hajna, A. A. & Perry, C. A. A Comparison of the Eijkman Test With Other Tests for Determining *E. coli*. *J. Bacteriol.*, 30:479 (1935).
29. Vaughn, R. H.; Levine, M; & Smith, H. A. A Buffered Boric Acid Lactose Medium for Enrichment and Presumptive Identification of *Escherichia coli*. *Food Research*, 16:10 (1951).
30. Eijkman, C. Fermentation Analysis at 46°C as an Aid in Drinking Water Examination. *Zentr. Bakteriol. Parasitenk.* (Ger.), 37:742 (1904).
31. Clark, H. F., et al. The Coliform Group. I. The Boric Acid Lactose Broth Reaction of Coliform IMViC Types. *Appl. Microbiol.*, 5:396 (1957).
32. Geldreich, E. E., et al. The Coliform Group. II. Reactions in EC Medium at 45°C. *Appl. Microbiol.*, 6:347 (1958).

Notes and Comment

Filter Sand Grain Growth Due to Manganese Dioxide

D. L. Erickson

Director, Dept. of Public Works & Utilities, Lincoln, Neb.

During 1959, at the request of AWWA Task Group 2680 P—Manganese in Water Supply, sand in four rapid filters at the Ashland Water Treatment Plant, which supplies water for the city of Lincoln, Neb., was examined for growth in size due to accumulation of manganese dioxide.

Samples were obtained by thrusting a 3-in. diameter shelby tube to a maximum depth of 18 in. or completely through the sand layer, whichever was less. The upper 3–4 in. of the sample was oven dried and then placed in dilute muriatic acid to remove the manganese dioxide. Sieve analyses were then made on the reclaimed sand.

Determinations of the apparent specific gravity were made (in accordance with ASTM D854) of the dried samples before they were placed in the acid solution and on the reclaimed sand. The weighted apparent specific gravity of the manganese dioxide was determined by calculation.

The thickness of the manganese dioxide accumulations (in microns) was determined from the surface area, specific gravity, and weight of the specific samples. The surface area data used in the calculations were obtained from a table found in a manual published by The Ohio Oil Co. in 1949 entitled *Fundamentals of Asphalt Paving.*

The results of the study are presented in Table 1. They are presented primarily for record purposes, and no conclusions are drawn as to their significance.

TABLE 1

Results of Study of Filter Sand Grain Growth Due to Manganese Dioxide, 1959

Datum	Filter No. 2	Filter No. 3	Filter No. 7	Filter No. 12
Year placed in operation	1954	1937	1949	1958
Sand reclaimed—*per cent*	96.4	70.4	82.5	96.1
Manganese dioxide—*per cent*	3.6	29.6	17.5	3.9
Apparent specific gravity				
Original sand	2.687	2.830	2.790	2.678
Reclaimed sand	2.666	2.648	2.664	2.667
Managanese dioxide	3.405	3.383	3.583	2.981
Surface area of sand—*sq/cm*	3,535	3,666	3,866	3,831
Avg thickness of manganese dioxide—μ	50	338	223	58

80th Annual Conference
Americana Hotel, Bal Harbour, Fla.
May 15–20, 1960

Convention Committees

Convention Management Committee

Representing AWWA

C. F. Wertz, *Chairman*

H. E. Keating — D. B. Preston
P. M. Keil — J. D. Roth
W. A. Oeffler — Garrett Sloan

Representing WSWMA

A. R. Murphy — E. K. Phelps

Ex Officio

Lauren W. Grayson, *President, AWWA*
Raymond J. Faust, *Secretary, AWWA*
E. Shaw Cole, *Chairman, AWWA Publications Committee*
George W. Kelsey, *President, WSWMA*
John G. Stewart, *Manager, WSWMA*

Convention Place Committee

Representing AWWA

Lewis S. Finch, *Chairman*

Lauren W. Grayson — Raymond J. Faust

Representing WSWMA

Edward E. Alt — George W. Kelsey
John G. Stewart

Technical Program Committee

E. Shaw Cole, *Chairman*

Charles A. Black — B. E. Payne
Albert R. Davis — William R. Seeger

Local Host and Information Committee

James B. Brown, *Chairman*

Sunday PM

C. A. Black, *Captain*

Ralph Baker Jr. — Cliff Earls
H. L. Berkstresser — Ike Pittman
C. E. Richheimer

Monday AM

R. F. Brennan, *Captain*

B. F. Borden Jr. — Jack Butler
R. L. Burdick — John Kelly
C. H. Stantor

Monday PM

W. B. Crow, *Captain*

Harold Briley — A. B. DeWolf
B. F. Crabbe — R. L. Quick
Stan Sweeney

Tuesday AM

J. R. Hoy, *Captain*

T. R. Finley — J. B. Miller
Nevin Hoy — A. O. Patterson
Ellis Phelps

Tuesday PM

W. W. Gillespie, *Captain*

E. C. Shreve Jr. — H. T. Skaggs
J. G. Simmons — F. B. Smith
J. W. Wakefield

1960 CONFERENCE STATISTICS

Bal Harbour Registration by Days

	Men	Ladies	Total
Preregistration	851	336	1,187
Sunday, May 15	808	400	1,208
Monday, May 16	397	138	535
Tuesday, May 17	67	5	72
Wednesday, May 18	22	—	22
Thursday, May 19	12	—	12
TOTALS	**2,157**	**879**	**3,036**

Geographic Distribution of Registrants

UNITED STATES

Alabama	93	Massachusetts	46	Tennessee	56
Arizona	14	Michigan	105	Texas	82
Arkansas	20	Minnesota	33	Utah	4
California	111	Mississippi	18	Virgin Islands	1
Colorado	20	Missouri	84	Virginia	52
Connecticut	27	Montana	3	Washington	16
Delaware	8	Nebraska	17	West Virginia	19
Dist. Columbia	29	New Hampshire	3	Wisconsin	47
Florida	299	New Jersey	174	Wyoming	1
Georgia	135	New Mexico	6		
Hawaii	2	New York	276	**CANADA**	
Idaho	4	North Carolina	60	Manitoba	1
Illinois	209	North Dakota	5	Ontario	76
Indiana	106	Ohio	164	Quebec	2
Iowa	56	Oklahoma	4		
Kansas	60	Oregon	16	**FOREIGN**	
Kentucky	41	Pennsylvania	255	Asia	4
Louisiana	44	Puerto Rico	6	Europe	10
Maine	4	Rhode Island	12	Latin America	19
Maryland	37	South Carolina	32		
		South Dakota	8	**TOTAL**	**3,036**

Comparative Registration Totals—1951–1960

Year	Place	Men	Ladies	Total
1960	Bal Harbour	2,157	879	3,036
1959	San Francisco	2,426	785	3,211
1958	Dallas	2,337	687	3,024
1957	Atlantic City	2,398	669	3,067
1956	St. Louis	2,026	510	2,536
1955	Chicago	2,075	512	2,587
1954	Seattle	1,536	527	2,063
1953	Grand Rapids	1,532	365	1,897
1952	Kansas City	1,600	386	1,986
1951	Miami	1,415	491	1,906

Win, Place & Show in Section Awards

Henshaw Cup		Hill Cup		Oak Oaken Bucket	
Cuban	**80.4%**	**Intermountain**	**102.99**	**California**	**1,671**
Pacific Northwest	73.0%	California	20.68	Southwest	1,006
North Carolina	71.4%	Iowa	16.29	New York	904

Wednesday AM

L. T. Faulk, *Captain*
Frank Bachmann F. A. Eidsness
M. R. Boyce D. B. Lee
C. H. McKinney

Publicity Committee

H. R. Wright, *Chairman* John A. Dacy

Local Transportation Committee

Joe De Marzio, *Chairman*
George Solberg Merle Taub

Plant Inspection Trip Committee

Jerry Tools, *Chairman* Guy C. Collins

Special Events Committee

Earl C. Crooks, *Chairman*
Francis L. Beveridge

Meet and Greet Night Committee

Jay D. Roth, *Chairman*
Kenneth T. Howe H. E. Keating

Awards and President's Reception

Honorary Chairmen—Awards

Lauren W. Grayson
A. P. Black P. S. Wilson

Honorary Chairmen—Reception

Mr. & Mrs. L. S. Finch
Mr. & Mrs. Fred Merryfield
Mr. and Mrs. Paul Weir

Local Committee

Garrett Sloan, *Chairman*
Walter Dinn W. W. Gillespie
A. P. Black J. R. Hoy
K. R. Chinn Howard Klein
C. E. Earls D. B. Lee
F. A. Eidsness H. T. Oberly
S. W. Wells

Golf Tournament

E. R. Crockett, *Chairman*

Beachcomber Party

David B. Preston, *Chairman*
R. J. Brehm G. C. Collins
J. D. Buckley D. W. Jones

Banquet and Ball

W. A. Oeffler, *Chairman*
R. C. Holman E. F. Kellerman
J. S. Whitney

Ladies Entertainment Committee

Clarence R. Henry, *Liaison Officer*

Mrs. Willard F. Rockwell Sr., *Co-Chairman*
Mrs. C. F. Wertz, *Co-Chairman*

Ladies Rendezvous—Mrs. Fred Eidsness & Mrs. Charles Black, *Co-Chairmen*

Tea West—Mrs. Earl Crooks, *Chairman*

Boat Tours—Mrs. David Preston & Mrs. J. D. Roth, *Co-Chairmen*

Luncheon & Fashion Show—Mrs. Paul Kiel, *Chairman*

Association Awards

Honorary Membership

Honorary Membership was conferred upon Raymond J. Faust, Edward R. Stapley, and Paul Weir. The citations follow:

RAYMOND JOHNS FAUST, Secretary, American Water Works Association, New York, N.Y.: *Member of the Association since 1938; Secretary-Treasurer Michigan Section 1938–41; Director 1950–51; Goodell Prize 1950; Fuller Award 1946; Executive Assistant Secretary of the Association 1951–59. Through his devotion to the fields of water supply and public health in Michigan and through his loyal and unswerving devotion to the interests of the members of the Association by his exemplary work and demand for quality water and service,*

R. J. Faust

E. R. Stapley

P. Weir

E. S. Cole

he has brought distinction to himself and honor to the profession to which he has been, and is, so dedicated.

EDWARD ROY STAPLEY, Dean Emeritus, College of Engineering, Oklahoma State University, Stillwater, Okla.: *Member of the Association since 1937; Director 1951–54; Fuller Award 1942. Engineer, teacher, and inspiring leader of students and fellow engineers. In more than 40 years of teaching and practice, he has been distinguished for his contributions to the improvement of public water supplies, to adult engineering education, research, and international relations. A splendid colleague in his many activities for the Association.*

PAUL WEIR, Manager, Atlanta (Ga.) Water Department: *Member of the Association since 1929; Chairman Southeastern Section 1939; Director 1943–46; President 1957; Goodell Prize 1941; Fuller Award 1940. A leader of many committees of the Association; his devotion to work, deep personal interest in his colleagues' welfare, and diplomatic talent have been melded by this gentleman to produce outstanding success in the management of his utility, and the appreciation of his community.*

Diven Medal

The John M. Diven Medal, awarded to the member whose services to the water utility field during the preceding year are deemed most outstanding, was presented to E. Shaw Cole. The citation follows:

EDWARD SHAW COLE, President, Pitometer Associates, New York, N.Y.: *for his diligent work and outstanding service to the Association in reorganization of the procedures for development of conference technical programs and for judging of published material eligible for Association awards.*

J. G. Carns Jr.

M. B. McPherson

J. V. Radziul

J. W. McFarland

A. P. Black

F. A. Eidsness

Publications Award

The AWWA Publications Award, granted for the best paper published in the JOURNAL from October 1958 through September 1959, was conferred upon James G. Carns Jr. The citation follows:

JAMES GIVIN CARNS JR., Meter Engineer, American Water Works Service Company, Philadelphia, Pa.: *for the manual "Water Meters—Selection, Installation, Testing, and Maintenance," published serially in the June, July, August, and September 1959 issues of the Journal and separately as AWWA Manual M6. In his capacity as chairman of a committee composed of both users and producers of water meters, he demonstrated not only unusual leadership and diligence, but editorial skill as well, in drawing together an eminently practical guide to the use and care of water meters. Meeting a long felt need, the manual promises to serve the field well for many years.*

Division Awards

Division Awards, granted for the best JOURNAL paper (October 1958–September 1959) in the field of interest of each of the four AWWA divisions, were presented to Murray B. McPherson and Joseph V. Radziul, John W. McFarland, A. P. Black and Fred A. Eidsness, and Earnest F. Gloyna and W. R. Drynan. The citations follow:

Distribution Division Award: MURRAY B. MCPHERSON, Professor of Hydraulic Engineering, University of Illinois, Urbana, Ill., and JOSEPH V. RADZIUL, Civil Engineer, Water Department, Philadelphia, Pa.: *for their paper "Distribution Design Considerations," published in the April 1959 issue of the Journal* (Vol. 51, page 489). *This paper provides a stimulating discussion of the new concepts in design made possible by new design tools and techniques. This contribution emphasizes the value of a modern approach to the solution of old problems.*

Management Division Award: JOHN W. MCFARLAND, General Manager, East Bay Municipal Utility District, Oakland, Calif.: *for his paper "Public Relations for a Modern Utility," published in the March 1959 issue of the Journal* (Vol. 51, page 305). *This paper, by example, indicates the many methods available to a modern water utility in winning the appreciation and support of its public and the value of using them.*

Purification Division Award: A. P. BLACK, Research Professor of Chemistry, University of Florida, Gainesville, Fla., and FRED A. EIDSNESS, Vice-President, Black & Associates, Inc., Gainesville, Fla.: *for their paper*

E. F. Gloyna

W. R. Drynan

"Electrophoretic Studies of Water Coagulation," published in the November 1958 issue of the Journal (Vol. 50, page 1467). *This paper described the application of a new analytic technique to the study of the complex mechanisms of coagulation and presented some preliminary results of its use that indicate its potentialities in developing a better understanding of coagulation. (Other authors of this paper were Janet B. Pilipovich, Research Assistant, and T. W. Stearns, Professor of Chemistry, also of the University of Florida.)*

Resources Division Award: EARNEST F. GLOYNA and W. R. DRYNAN, both of the Civil Engineering Department, University of Texas, Austin, Tex.: *for their paper "Water Reuse in Texas," published in the June 1959 issue of the Journal* (Vol. 51, page 768). *This paper, in describing an intensive survey of the waste waters of Texas, not only exemplifies a new kind of planning and research, but a new approach to water resources. (The third author of this paper was E. R. Hermann, Industrial Hygienist, Humble Oil & Refining Co., Baytown, Tex.)*

Safety Awards

The Wendell R. LaDue Safety Awards, granted to utilities for outstanding accomplishments in safety during a calender year, were presented to the Knoxville (Tenn.) Suburban Utility District, the Brookline (Mass.) Water Dept., and the Knoxville (Tenn.) Bureau of Water. The citations follow:

Class 1: KNOXVILLE (Tenn.) SUBURBAN UTILITY DISTRICT, Carl L. Webb, President: *for a perfect 1959 safety record covering 18,232 man-hours of work by 6 employees, following a perfect record of no lost-time injuries since 1950.*

Class 2: BROOKLINE (Mass.) WATER DEPT., Kenneth W. Robie, Superintendent: *for a perfect 1959 safety record covering 108,000 man-hours of work by 54 employees, following a perfect record during 1958.*

Class 3: KNOXVILLE (Tenn.) BUREAU OF WATER, Ernest D. Hawkins, Superintendent: *for a perfect 1959 safety record covering 489,085 man-hours of work by 226 employees.*

Scholarship Award

The Harry E. Jordan Scholarship Award, granted to further the education of deserving applicants from the West (a different region is selected each year), was conferred upon Jack D. Smith, a graduate student in sanitary engineering at Oregon State College, Corvallis, Ore. [The award was presented at the meeting of the Pacific Northwest Section.]

Fuller Awards

The George Warren Fuller Awards were presented to 30 men whose sections had nominated them in the year beginning with the 1959 Annual Conference at San Francisco and ending with the opening of the 1960 Conference at Bal Harbour. The awards—which are conferred for "distinguished service in the water supply field and in commemoration of the sound engineering skill, the brilliant diplomatic talent, and the constructive leadership of men in the Association which characterized the life of George Warren Fuller"—went to the following men:

Alabama-Mississippi Section—CLIFTON CURTIS WILLIAMS: *who has given unselfishly of his time and his talents to promote the healthy growth of the section; his friendly personality, his*

mitless energy, and unfailing optimism have been an inspiration to all who have known and worked with him.

Arizona Section—ABRAHAM LINCOLN FRICK JR.: *in recognition of his valuable contributions and services in the field of water treatment over the past 30 years and his extraordinary activities in furthering the Arizona Section as organizer, counselor, and officer.*

California Section—EDWARD ALEXANDER REINKE: *for his outstanding service to the people and the water utilities of California in helping to promote and maintain the present high standards of water quality and sanitary control of water supplies; and for his many and continuing services to the section.*

Canadian Section—CLARENCE STEWART ANDERSON: *for his outstanding support of water works development and for his many years of effective participation in the activities of the Canadian Section.*

Chesapeake Section—WILLIAM COMPTON WILLS: *for his exemplary service as chief engineer of the Wilmington water utility, including the development and responsibility for the modernization of that system; and for his long service to and interest in the affairs of this Association.*

Cuban Section—MANUEL F. DE-VERA: *for his untiring efforts in behalf of the Cuban Section, particularly during its most difficult years, when, as chairman, he guided the section with wisdom and integrity; also for his extraordinary interest in all phases of water supply and the many valuable papers he has presented.*

Florida Section—DONOVAN WARNER JONES: *an outstanding water utility manager, a leader in all community affairs, and a devoted member of the Florida Section, which he served as chairman.*

Illinois Section—JOHN P. HARRIS: *for his unselfish assistance to water plant operators; his continuing efforts for the advancement of knowledge among water utility men in Illinois through his active participation in water works schools and short courses; and for his loyalty and service to the section.*

Indiana Section—CLYDE ELMER WILLIAMS: *for his distinguished service as Association director, chairman, and committeeman; and in recognition of his sound and ethical practices and his promotion of the highest ideals of the engineering profession in the water works field.*

Iowa Section—WARNER JOHN LANG: *for his loyal participation as a member and past officer of the Iowa Section; for his improvement of the stature of water utility personnel; and for the advancement of water works practices in his community.*

Kansas Section—HOWARD ALEXANDER STOLTENBERG: *for his distinguished service to the section, particularly his constructive leadership and guidance of the operators' certification program, his valuable participation in conducting operator training schools, and his noteworthy contributions to research on water analysis and purification methods.*

Kentucky-Tennessee Section—JOHN WESLEY MCCOY: *in recognition of his untiring personal efforts in conducting training courses among water plant operators and his efforts in connection with the water plant operators licensing program, the annual operators school, and section programs.*

Michigan Section—GEORGE JOHN HAZEY: *for his inquiring approach and*

administrative ability directed toward treatment and distribution of water; for his unstinting services to the Association both on committees and as an officer; and for his many contributions to the section's technical programs.

Missouri Section—JAMES BUTLER RAMSEY: *for his outstanding work in the safety program of the Association, his zeal in discharging his committee obligations, and his courage in the face of adversity, which marks him as a true disciple of George Warren Fuller.*

Montana Section—EDWARD R. WALDO: *in recognition of his managerial, public relations, and employee relations accomplishments which have secured for his community a water supply adequate for many years to come; and for his faithful service to the section and the Association.*

Nebraska Section—RALPH H. LANCASTER: *for his exceptional interest in the proper operation of a smaller utility and his loyal support of the activities of the Nebraska Section.*

New England Section—DONALD CAMERON CALDERWOOD: *for his able administration and development of a private water utility; for his inspiring leadership in the advancement of the water works industry in New England; and for his dedicated service to the public in the conservation of water resources through pollution control.*

New Jersey Section—CHARLES JOSEPH ALFKE: *for his forceful leadership of the water works industry in his state; his wartime cooperation with the New Jersey Joint Operation Board; his service to the New Jersey Section as chairman and director; and his services on important committees of the Association.*

New York Section—ALFRED MOSS ROBERT: *for his skill in management and engineering within the water supply field and for his pioneering efforts in promoting regional meetings, which have resulted in improvement of knowledge and interplant exchange of water works equipment and supplies during emergency situations.*

North Carolina Section—JAMES MAURICE JARRETT: *for his outstanding service as a leader and officer in the section and for service to the water utility field as a sanitary engineer with public agencies.*

North Central Section—ROBERT MELVIN JENSON: *for his many years of participation in all affairs of the section, including his devoted service as an officer and diligent worker on many committees; and for his accomplishments as head of the water utility of his community.*

Ohio Section—DONALD DANZ HEFFELFINGER: *for his sound technical and administrative ability in the field of water supply; for his unselfish service to the Ohio Section as a member, committee chairman, officer, and director; and for his contribution to the water utility profession as an engineer.*

Pacific Northwest Section—CHARLES RAYMOND HARLOCK: *for his contributions to the water treatment field; his devotion to the Association; and for his generous sharing of knowledge with his colleagues.*

Pennsylvania Section—FRANCIS DE-SALES FRIEL: *in recognition of the eminence he has achieved in the field of engineering and the outstanding service he has rendered to the water utility profession and to this section.*

Rocky Mountain Section—ROBERT PEARSON LOWE: *for his untiring efforts in the successful promotion and operation of the water works school in New Mexico and for the success of the annual meetings of the Rocky Mountain Section held in Santa Fe.*

Southeastern Section—THOMAS ALBERT JONES: *in recognition of his long*

and distinguished service in the field of water supply and his loyal and faithful support of the Association.

Southwest Section—JOHN BLEECKER LUCE: *in recognition of his unceasing efforts for mandatory licensing laws for water utility operators in Arkansas, for betterment of the environmental aspects of public health, and for his efforts, as a member of Arkansas Water Conservation Commission, in obtaining favorable consideration for public water supplies.*

Virginia Section—EUGENE COLES MEREDITH: *for his sound and understanding leadership in the field of public health; for his services to the Virginia Section as treasurer, chairman, and director; and for his continued interest and participation in section affairs.*

West Virginia Section—HUGH WELLS HETZER: *for his long service to the water utility field; his active participation in improving the quality of conference programs; his cooperation in presenting short courses for water plant operators; and his untiring efforts as secretary-treasurer of the section.*

Wisconsin Section—BRUNO JOSEPH HARTMAN: *for his many years of devoted activity in section affairs; for the many hours spent in preparation and presentation of valuable papers before the section; for the high standard of his professional ethics and his services to water utilities.*

Schedule of Conference Papers and Reports

MONDAY MORNING, May 16

General Session

President's Address.....Lauren W. Grayson
Challenges of the Water Industry.....Raymond J. Faust
Aims and Objectives—Committee Report.....Fred A. Eidsness
The Importance of Highway and Utility Liaison.....Sam Houston

MONDAY AFTERNOON, May 16

Management Division—Research

Research in the United States.....Harry A. Faber
Research in Canada.....Albert E. Berry
Research in the United Kingdom.....R. G. Allen
What AWWA Should Be Doing in Research—Open Discussion..*Led by* Thurston E. Larson

Water Resources Division—Ground Water

Quality and Waste Disposal.....Matthew Irvin Rorabaugh
Salt Water Encroachment.....Francis A. Kohout
Recharge—Panel Discussion
Richard T. Sniegocki, W. L. Broadhurst, W. Fred Welsch, Glenn R. Hotchkiss, & Frank H. Dotterweich

TUESDAY MORNING, May 17

Water Works Administration Committee—Open Session

Purification Division—Water Standards

Introduction.....Ray L. Derby
New US Public Health Service Drinking Water Standards..O. C. Hopkins & Oscar Gullans

Water Quality Standard.....Elwood L. Bear
Operator's Viewpoint.....John R. Baylis
Legal Viewpoint.....Frank E. Maloney

TUESDAY AFTERNOON, May 17

Management Division—Commercial

Machine Billing Procedures—Joint Discussion.....R. D. Tompkins & John G. Copley
Administrative Manuals.....William D. Hurst
Present Philosophies of Rate Making.....Samuel S. Baxter

Distribution Division—Water Mains

Water Main Breaks—Panel Discussion
Led by Gerald E. Arnold, Edward J. Clark, Gerald Remus & Howard W. Niemeyer
Extension Policies.....Henry J. Graeser
Loss of Pipeline Carrying Capacity.....Thurston E. Larson

Water Resources Division—Water Storage

Joint Sealing in Concrete-Paved Reservoirs.....H. Ward Tyler
Underground Waste Disposal—Task Group Report.....Lynn M. Miller
Ground Water Recharge—Task Group Report.....John J. Baffa
The Automatic Rubber Diversion Dam in the Los Angeles River.....N. M. Imbertson

WEDNESDAY MORNING, May 18

General Session

Rich Harbor—Motion Picture.....Commonwealth of Puerto Rico
US Water Resources.....Theodore M. Schad
Protection of Water Resources.....Mark D. Hollis
Water Resources in Florida.....John W. Wakefield
New Constitution and Bylaws.....Lauren W. Grayson

WEDNESDAY AFTERNOON, May 18

Water Works Practice Committee—Open Session

Revision of Positive-Displacement Meter Standard.....James G. Carns Jr.
Concrete Pressure Pipe in Today's Water Works Industry.....Ernest W. Whitlock
Progress in Certification.....Lewis S. Finch
Steel Tank Painting—Including Resins.....J. O. Jackson
High-Tensile Steel.....Louis R. Howson

Purification Division—Coagulation and Reports

Coagulation.....A. P. Black
Discussion.....Rolf Eliassen
Recovery and Reuse of Alum Sludge.....J. M. Roberts
Comparison of Various State Water Works Criteria.....William W. Aultman

THURSDAY MORNING, May 19

Water Resources Division—Surface Supplies

A New Look at Streamflow Data.....Joseph VanBrunt Wells
The Everglades—Past, Present, and Future.....Paul Troxler
Taste and Odor Problems in New Reservoirs Located in Wooded Areas....E. Jerry Allen

rogress in Water Desalting.....Allen Cywin & Lewis S. Finch
Vater for Tomorrow.....Gordon E. McCallum & Robert W. Haywood Jr.

Distribution Division—Pipe, Coatings and Construction

Drop of Water—Motion Picture.....Pinellas County Water System
eport on Copper Water Service Study.....Kenneth E. Shull
lastics and Plastic Pipe.....R. J. Sweitzer
ome Solutions to Unusual Pipeline Construction Problems
H. Arthur Price, Harold L. Gunther & Dean C. Noll
poxy Resin Coatings for Water Works Facilities and Equipment.....Loring E. Tabor

Vater Utility Management Division Advancement Session—Financing Water Utilities

he Advancement Program Accomplishments.....Fred Merryfield
ennies for Health—Motion Picture.....National Water Institute
low Bond Issues Were Passed
Fergus Falls, Minn.....Howard Sowden
Denver, Colo.....Robert S. Millar
ommunity Relations Is a Day-to-Day Job.....Thomas F. O'Leary

THURSDAY AFTERNOON, May 19

Water Distribution and Water Utility Management Divisions—Joint Session

Bull Run Water Supply—Motion Picture.....Portland Bureau of Water Works
Water Demands—Progress Report.....H. E. Hudson Jr.
Submersible Water Well Pumps.....Claud R. Erickson
Establishment and Use of Work Standards in Utility Maintenance and Construction
Charles B. Adelmann
Duties and Responsibilities of the Utility Manager.....William R. Seeger

Purification Division—Pollutants in Water

Estimating Human Radiation Exposure Along the Animas River
E. C. Tsivoglou, S. D. Shearer, John D. Jones & Don A. Clark
Pollutants in Water—Panel Discussion
Effects of Fertilizers, Pesticides, and Other Materials in Watershed Runoff
Clarence M. Tarzwell
Effects of Salinity Caused by Irrigation.....L. V. Wilcox
Effects of Sewage and Industrial Wastes.....Ralph E. Fuhrman
Effects of Syndets.....Graham Walton
Effects on Taste and Odors.....H. O. Hartung

Social Calendar

Sunday	12:00 Noon	Exhibit Open House	Grand Ballroom, Americana Hotel
	6:00 PM	Meet & Greet Night	Starlite Patio, Americana Hotel
Monday	2:00 PM	Tea West	Westward Room, Americana Hotel
	8:30 PM	Awards and President's Reception	International Room, Americana Hotel

Tuesday	8:00 AM	Annual Golf Tournament	Diplomat Golf & Country Club
	10:00 AM	Boat Tour	
	8:30 PM	Beachcomber Party	Starlite Patio, Americana Hotel
Wednesday	11:00 AM	Luncheon and Fashion Show	Deauville Hotel
	Evening	No scheduled entertainment	
Thursday	10:00 AM	Boat Tour	
	6:30 PM	Annual Banquet and Ball	International Room, Amer cana Hotel

Exhibitors

Allis-Chalmers Mfg. Co.
American Cast Iron Pipe Co.
American City Magazine
American Steel Foundries, Griffin Pipe Div.
American Water Works Assn., Public Relations
American Well Works
Armco Drainage & Metal Products, Inc.
Badger Meter Mfg. Co.
Baker, R. H. & Co., Inc.
B-I-F Industries, Inc.
Brooks Products, Inc.
Brainard, F. S., & Co.
Buffalo Meter Co., Inc.
Burgess-Manning Co.
Calmet Meter Div., Worthington Corp.
Centriline Corp.
Chain Belt Co.
Chicago Bridge & Iron Co.
Clow, James B., & Sons, Inc.
Darling Valve & Mfg. Co.
DeLaval Steam Turbine Co.
Dorr-Oliver Inc.
Dresser Mfg. Div.
Eimco Corp.
Electro Rust-Proofing Corp.
Engineering News-Record
Filtration Equipment Corp.
Fischer & Porter Co.
Fisher Research Lab., Inc.
Fog-Tite Meter Seal Co.
Ford Meter Box Co., Inc.
Foster Eng. Div., General Controls Co.
Foxboro Co.
Gamon Meter Div., Worthington Corp.
Glamorgan Pipe & Foundry Co.
Glenfield & Kennedy, Inc.
Golden-Anderson Valve Specialty Co.
Graver Tank & Mfg. Co., Div. Union Tank Car Co.
Hach Co.
Hagan Chemicals & Controls, Inc.
Halliburton Oil Well Cementing Co., Water Well Services Div.
Hammarlund Mfg. Co., Inc.
Hanks, Fred W., Co.
Harco Corp.
Hellige, Inc.
Hersey-Sparling Meter Co.
Homelite, Div. of Textron, Inc.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.
Inertol Co., Inc.
Infilco Inc.
Johns-Manville
Keasbey & Mattison Co.
Koppers Co., Inc., Tar Products Div.
Layne & Bowler, Inc.
Leopold, F. B., Co., Inc.
Link-Belt Co.
Lock Joint Pipe Co.
Ludlow Valve Mfg. Co., Inc.
McWane Cast Iron Pipe Co.
M & H Valve & Fittings Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
National Water Main Cleaning Co.
Neptune Meter Co.
Peerless Pump, Hydrodynamics Div.
Permutit Co.
Philadelphia Gear Corp.
Pittsburgh-Des Moines Steel Co.
Pollard, Joseph G., Co., Inc.
Preload Co., Inc.
Price Brothers Co.
Public Works Publications
Roberts Filter Mfg. Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co., Inc.
Scranton Publishing Co.
Smith, A. P., Mfg. Co.
Smith-Blair, Inc.
Sparkler Mfg. Co.
Stuart Corp.
Trinity Valley Iron & Steel Co.
Tyler Pipe & Foundry Co.
United States Pipe & Foundry Co.
Wachs, E. H., Co.
Walker Process Equipment Inc.
Wallace & Tiernan Inc.
Water Works Engineering
Welsbach Corp.
Wheeler, C. H., Mfg. Co.
Willamette Iron & Steel Co.
Wood, R. D., Co.

Papers Scheduled at 1960 Section Meetings

THERE follows a summary listing of papers scheduled for presentation at 1960 section meetings. The dates of the section meetings from 1956 to 1960 and the locations for 1960 are listed on page 1605. Section officers who were elected at meetings held during 1960 are listed on page 2 P&R in the front of this issue. The programs are listed alphabetically by sections, without regard to the date of presentation.

Alabama-Mississippi Section—Oct. 9–12, 1960

Address of Welcome.....*Mayor* James W. Morgan
The Role of Federal Departments in Times of Disaster.....J. A. Boyer
The Relocation of Utility Facilities on Highways.....Harry B. Lackey
AWWA Can Help You Help Yourself.....James B. Corey
The Part Specifications Play in Purchasing—Panel Discussion.....*Led by* Cliff Williams
Manager's Viewpoint.....Tom Collins
Consulting Engineer's Viewpoint.....James E. Jagger
Salesman's Viewpoint.....Scott Lyles
Chemical Problems in Treating Water, Present and Future.....Carl Wittichen
Let's Talk About AWWA.....Jess Haley
Ductile Iron, the Miracle of Modern Metallurgy.....Warren Jeffery
Why Cheap Water?.....Morgan Stickney & Ed Love
Public Relations.....Warren Whitney
Water Treatment at Redstone Arsenal—Its Relationship to the Mission and Impact on Economy.....Niles A. Prestage

Arizona Section—Apr. 28–30, 1960

Address of Welcome.....*Mayor* Don Hummel
City of Tucson Water Expansion.....Porter W. Homer
Urban Versus Rural Pollution Affecting Receiving Waters in the Imperial Valley.....Harvey F. Ludwig
Ground Water Reserves and Economic Factors Pertaining to Arizona.....John W. Harshbarger
Steel Pipe Design and Application.....Bill Wolfe
Instrumentation—Its Purpose and Results in the Water and Waste Field..Richard M. Day
New Standards—Water and Sewage.....Karl Hirlinger
Water Rates.....Carl Schmidt
Settling-Tank Maintenance at Hyperion.....Glenn Thwaytes
Taste and Odor Control in Water Supply.....E. A. Sigworth
Public Utilities Rights-of-Way.....Hank Goudy
Motion Picture: Water Is the Foundation of Life

California Section—Apr. 22, 1960

Address of Welcome.....*Mayor* Shedo Russo
Disinfection of a Surface Water Supply by Dual Chlorination.....Leland G. Bennett
Revenue Bond Financing for Municipal Utilities.....Frank Twohy
Deleting Drafting Drudgery.....Bruce B. Grant

State Water Development Program—Panel Discussion.....*Led by* Samuel B. Morris
What the Water Development Program Means to California.....William L. Berry
Viewpoint of Agencies Contracting for Water With the State.....Herbert G. Crowle
Legislative Aspects.....Carley V. Porter
Credit and Debit Management—Key Factors in California's Capacity to Finance the $1,750,000,000 Water Program.....James M. Wiler

California Section—Oct. 24–27, 1960

Address of Welcome.....*Mayor* Edwin W. Wade
Progress in Subsidence Control in Long Beach.....Charles Vickers
Problems of System Expansion by Annexation of Existing Systems.....H. B. Fisher
Developing a Rational Meter Program.....Harold E. Wilson
Is Our Present Depreciation Practice Antiquated?.....William C. Welmon
Penniless Accounting.....John F. Donovan
Business Management Division Aims and Objectives.....William R. Seeger
Taste and Odor Control Practices in California.....E. A. Sigworth
Chlorination of Dilute Nitrogenous Materials.....William R. Samples
Manganese Deposits in Reservoirs and Distribution Systems.....Henry C. Myers
Algae and Other Interference Organisms in Water Supplies of the Southwest.....
C. Mervin Palmer
Electric Grounding Requirements Versus Water Utility Practices.....
G. A. Clark & Lee B. Hertzberg
Radio Indication of Automatic Operation of Remote Valves.....James Stannard
Commonly Misunderstood Features of the Grading Schedule of the National Board of Fire Underwriters.....Kenneth J. Carl
Fire Protection Requirements in Unincorporated Areas
John A. Lambie & Harvey T. Brandt
Water Rights—A Lucrative New Tax Source.....C. Marvin Brewer
Shopping Malls—How Do They Affect Water Utilities?
City Problems.....Kieth F. Mulrooney
Water Problems.....James Van Wagner
Fire Problems.....Loren S. Bush
Landscaping of Utility Structures in Residential Areas..W. T. Hartman & Fred Tschopp
Coastal Ground Water—A Neglected Resource.....C. E. Jacob
Organization and Operation of a Water Replenishment District.....Howard W. Crooke
Safety in the Sixties.....Joseph M. Kaplan
Automatic Alarm System for Detecting Chlorine Leaks in Unattended Stations.....
William R. Ree
A Look at the Distant Future of the Water Works Industry.....Harold H. Yackey

Canadian Section—Apr. 24–27, 1960

Address of Welcome.....*Mayor* Frank A. Sedita
Water Service to Other Municipalities.....G. H. Baker
The Art of Communication.....G. E. Symons
Feeding of Liquids and Solids in Water Works.....O. K. G. Mang
Industrial and Agricultural Poisons in Water Supplies.....Richard L. Woodward
Distribution System Maintenance.....G. Earle Maxwell
Water Treatment and Distribution for the City of Buffalo.....Frank O'B. Nehin
The Principles of Rate-Making Procedure and Problems of Financing..John W. Churchill
Modern Methods in Water Analyses.....J. H. Neil, C. E. Simpson & L. T. Vlassoff
Short Filter Runs Due to the Presence of Diatoms.....Jean C. Bouchard
Facilities Required and the Methods of Financing for Fire Protection in the Municipal Water Works.....W. H. Powell

Canadian Section—Maritime Branch—Sep. 28–30, 1960

Miscellaneous Water Works Problems.....J. W. Reside
Fire Protection Responsibilities.....W. G. Shakespeare
Recent Developments in the Greater Saint John Water System.....A. E. Hanson
Management and Office Procedures.....N. C. Cohoon
Management and Labor in the Water Industry—Discussion.....*Led by* W. W. Reid, J. W. Churchill, M. A. Hughes & W. A. Barrett

Chesapeake Section—Nov. 2–4, 1960

Address of Welcome.....*Colonel* Frederick J. Clarke
Effect of Impoundment on Water Quality.....S. Kenneth Love
Certification and Education of Operators.....W. McLean Bingley
Significant Revisions in the Drinking-Water Standards.....George Burke
Utilization of Watershed Properties for Recreation.....L. V. Schuerholz
Potential Health Hazards of Viruses, Nematodes, and Ameba in Public Water Supplies.. Shih Lu Chang
Status of Long-Range Water Supply Planning for the Washington Metropolitan Area—Panel Discussion.....*Led by* David W. Auld
The District of Columbia.....Harry E. Schwarz
The Washington Metropolitan Region of Maryland.....Robert J. McLeod
Northern Virginia.....James J. Corbalis Jr.
Water Supply Protection.....Norman E. Jackson
The Potomac River Filter Plant of the Washington Suburban Sanitary Commission..... Roy H. Ritter
An Environmental Monitoring Program for a Nuclear Facility.....J. L. Allen
Ductile-Iron Pipe for Water Mains.....Charles E. Smith
Magnetic-Flow Meters.....Leo Carroll
Remote-Reading Consumer Meters.....Jerome B. Wolff
Practical Applications of Epoxy Resins and Attendant Difficulties.....Morris R. Smith
Effects of Urbanization on Sediment in Streams.....Harold P. Guy
Use of Polyelectrolytes in Water Treatment.....Floyd B. Taylor
Use of Short-Wave Radio in Telemetering.....Harrison T. Randolph
Motion Picture: Pure Water and Public Health

Connecticut Section—Oct. 6, 1960

Theories and Principles of Water Main Extensions.....Elmer C. Neusse
Connecticut's Public Water Supply—Present and Future.....Warren J. Scott

Florida Section—Nov. 13–16, 1960

Address of Welcome.....*Mayor* Edward H. Johns
Economical Desalting of Brackish Waters by Electrodialysis.....Kenneth G. Barnhill
Water Consumption Rates Effecting Small Treatment Plant Design....Phillip E. Searcy
Policies of the Central and Southern Florida Flood Control District With Regards to Protection of Ground Water Supply and Disposal of Sewage Treatment Plant Effluent... William V. Storch
Report on the Department of Water Resources.....John W. Wakefield
The Water and Sewage Utility in Florida—Panel Discussion.....*Led by* F. A. Eidsness
Water and Sewage Rate Structure.....Arthur W. Saarinen Jr.

Extension Policies.....Garrett Sloan
Value and Depreciation.....Walter R. Avery
Operation of Private Utilities Under State Requirements.....Larry Johnson
Motion Picture: A Drop of Water

Illinois Section—Mar. 16–18, 1960

Address of Welcome.....*Mayor* Richard J. Daley
Demand Rates in Water Utilities.....Arthur Rynders
Sewer Service Charges on Water Bills.....John H. Hunter & Edward J. Tobin
Experiences in the Use of the Electronic Computer in the Analysis of Water Supply Problems.....E. M. Chastain
Safety.....H. R. Frye
Accidents Due to Lack of Oxygen
In Tanks, Manholes, and Excavations.....Paul Sheppard
In the Plant.....Timothy D. Nulty
Peoria Taps the Illinois River.....Howard J. Carlock
Improvements at Quincy's Water Plant.....W. R. Gelston
Water and Sewage Facilities on the Illinois Tollway.....George L. Jackson
Water Systems Around the World.....C. W. Klassen
Water Utility Advancement—Panel Discussion.....*Led by* Edward R. Healy
A Business Man.....Victor E. Fishburn
A Consulting Engineer.....Donald M. Maxwell
A Utility Manager.....Clifford Fore
A State Agency Representative.....William Ackerman
Effects of Phosphates on Coagulations and Sedimentation of Turbid Waters.....James J. Morgan
Circulation of Water in a Distribution System.....T. E. Larson, John C. Guillou & Laurel Henley
Operators Forum—Panel Discussion.....*Led by* Edward E. Alt
Tank Maintenance.....Edward E. Alt
Chemical-Feeding Problems.....Oscar Gullans
Peak Water Demands.....Richard Schlaack
A Subdivision Water Supply.....L. J. Morgan
Applications of Small Meters.....Joseph H. Kuranz & Arthur P. Kuranz
Effective Economies in Water System Operations.....Leo Louis
Motion Pictures: The Dresden Sphere; Industrial Hygiene and Safety—Breathe and Live; Priceless Water; Conference Report

Indiana Section—Feb. 3–5, 1960

Address of Welcome.....Harvey Wilke
Your Water Works—Does It Measure up to Requirements?—Panel Discussion.....*Led by* Lewis S. Finch
Future Demands.....B. A. Poole
Fire Protection.....George Stahl
Hydraulic Surveys.....W. D. Hudson
Management and Adequate Rates.....Wendell R. LaDue
Automation and Automatic Pump Controls for Everyone—Panel Discussion.....*Led by* O. W. Summers
Manufacturers' Viewpoint.....Charles S. Harris
Application Example.....Ray C. Haller
Maintenance.....Walter Huff

Humidity Control in Water Plants
General Application.....Walter Kinnard
Application Example.....Harry D. Harman
Water—The People's Business.....James B. Corey
Water Cocktail on the Rocks.....C. F. Wertz
How Russia Looks to an Engineer.....William S. Foster
What's New
In Plastic Pipe.....G. H. Reed
In Cast-Iron Pipe.....Thomas F. Wolfe
In Copper Pipe.....A. J. Heim
In Tools and Gadgets.....H. W. Niemeyer

Intermountain Section—Oct. 6–7, 1960

Address of Welcome.....*Commissioner* Conrad B. Harrison
Watershed Management and Water Works, an Essential Alliance.....Otis L. Copeland
Ground Waste Disposal as it Affects Water Supply.....Lynn M. Thatcher
Chlorine Installations.....Ken Keirn
Modern Practices in Water Main Cleaning.....J. A. Frank
Public Relations.....Henry Oddie
Protective Municipal Water Supply Against Radioactive Substances..Richard L. Woodward
Water Main Extension Policy—Panel Discussion.....*Led by* Robert F. Hamilton, H. H. Ballenger, Donald F. Lloyd, Dallas E. Jeppsen & Eldon McEntire
Repair and Sterilization of Distribution Mains After a Major Break..W. Franklin Richards
Water Works Accounting Procedure as it Affects Bonding.....J. A. Burrows
Standards for Dissolved Minerals and Other Substances in Water Supply..... Richard L. Woodward
Taste and Odor Conditions in the Intermountain Section Versus the United States..... E. A. Sigworth
Problems Encountered in Starting a New Water Treatment Plant..Vaughn B. Wonnacott

Iowa Section—Oct. 19–21, 1960

Address of Welcome.....*Mayor* Reinhold O. Carlson
A Challenge to Our Industry.....Raymond J. Faust
Pressure Pumping Versus Elevated Storage.....Paul Kuhn
Water Pollutants of Tomorrow.....Gordon G. Robek
What, When, and How to Inform the Public.....Walter Shotwell
Utility Relocation Financing.....James E. Thompson
Water Utility Advancement.....George C. Ahrens
Iron Problems—Panel Discussion.....*Led by* D. Y. Caldwell
Red-Water Studies in Omaha.....Joe Erdei
Iron Bacteria.....Charles N. Brown
Iron Removal by Diatomaceous Earth Filters.....Paul Morgan
What the Water Works Man Needs to Know About Management.....William S. Foster
General Aspects of Water Works Instrumentation.....Leo Cunningham
Legal Liabilities and Problems of Water Utilities.....George C. Ahrens

Kansas Section—Apr. 20–22, 1960

Address of Welcome.....*Mayor* G. S. Groh
Relationship of the City, the Consulting Engineer and the Contractor on Utility Construction Projects—Panel Discussion.....*Led by* Russell L. Culp, Fred L. Kramer, Elmer N. Pearse & Claude Rhoades

Problems Confronting the Consulting Engineer in Designing New Improvements for a Municipality.....O. O. Ediger
Four Parties and a Maintenance Clause.....J. H. Holloway
Aquifer Testing for Ground Water Supply—Panel Discussion....*Led by* L. E. Ordelheide, G. J. Stramel & R. O. Joslyn
Plastic Pipe for Water Service.....Robert P. Selm
Water Cocktail on the Rocks.....C. F. Wertz
Water Works Advancement.....H. H. Kansteiner
Taste and Odor Problems in Surface Waters.....D. W. Ryckman
Water Chlorination Practices in Kansas.....Russell L. Culp
Sludge Blanket Treatment of Water.....J. S. Kneale
Status of Retirement Program for Public Employees.....F. D. Diehl
Effects of the Safety Program on the Water Works Industry.....Orville G. Kuran
Accounting Procedures for Small Municipal Utilities.....S. C. Whiteaker
Motion Pictures: Snows of Tutupaca; What's in It for Us?

Kentucky-Tennessee Section—Sep. 11–14, 1960

Address of Welcome.....*Mayor* John J. Duncan
What AWWA Can and Should Be Doing to Help Its Membership in Meeting the Current Challenges of the Water Works Industry.....John W. Cramer
Annexation Problems—Effects on Water and Sewer Systems—Panel Discussion..... *Led by* J. Wiley Finney Jr.
Advance Planning in Memphis.....Justin J. Davis
Consultant's Viewpoint.....G. R. Watkins
Murfreesboro Experience.....E. L. Johnson
Problems General to Annexation.....Victor C. Hobday
Detergent Removal and Taste and Odor Control.....E. A. Sigworth
Stream Pollution Control.....Harold V. Miller & John R. Thoman
Utility Districts.....Edward S. Overman
New Federal Drinking Water Standards.....Julian R. Fleming
National Board of Fire Underwriters Rating System Applicable to a City's Water System—Methods and Procedures.....W. J. Dahlgren
Water Main Extension Policies—Panel Discussion .....*Led by* Jack D. Boxley, Merrill L. West, Elmer Smith, Joseph B. Irwin & John T. Cunningham Jr.
Modern Techniques in the Reproduction and Retention of Permanent Records..... Robert M. Walker Jr.
Considerations Involved in Differential Water Rates and Service to Repump Areas..... M. L. Brickey
Progress Report of the AWWA Safety Programs in the Kentucky-Tennessee Section.... Fred C. Prince
Blasting Claims—Investigations and Evaluations.....Ben L. Greene
Machine Billing and Customer Accounting.....C. F. Wahli
Motion Pictures: Pure Water and Public Health; Pure and Simple

Michigan Section—Sep. 21–23, 1960

Address of Welcome.....*Mayor* Hugh R. Murchie
Cadillac Is Solving a Water Supply Problem—Panel Discussion..*Led by* T. Walter Kelly
Location and Evaluation of Ground Water.....Lynn M. Miller
Distribution, Pumping, and Storage.....Harold A. Kelley
Detergents.....Gordon Olivier

Taste and Odor Problems in Michigan as Compared to Europe.....E. A. Sigworth
Pretreatment—A Comparison of Plant Operation Results.....A. M. Shannon
Recent Developments in Coagulant Aids.....Jack Borchardt
Service Lines and Customer Meters—Panel Discussion.....*Led by* Glen D. Heggie, Barney Giffin, Al Sabo, Alex M. Krzyminski & W. F. Marklund
Cleaning of Deep Wells and Pumps.....Claud Erickson
Experience with Ductile Pipe.....Al Sabo
Ionia Provides Water for Industry.....Anthony Balice & Raymond Smit
Report on National Efforts to Improve AWWA Standards of Water Works Materials... Gerald Remus
Challenges of the Water Industry.....Raymond J. Faust
Procedures and Requirements for Subdivision Ground Water Supplies in Townships—Panel Discussion.....*Led by* C. C. Crumley, Felix Anderson, James Scott, James E. Seetekin & John Waroz
Recharge in the Kalamazoo Area.....Al Sabo

Missouri Section—Sep. 25–27, 1960

Address of Welcome.....*Governor* James Blair
How Can AWWA Help You in Meeting the Challenges of the Water Works Industry?.. John W. Cramer
Coagulant Aids—As Approved by the USPHS Technical Advisory Committee..... Richard Reavis
New Tools for the Water Plant Operators—Coagulant Aids.....Curtis E. Moutrey
Compensation of Water Works Personnel.....Garvin Dyer
Challenges of the Water Works Industry.....Raymond J. Faust
Water and Sewage Facilities and the Highway Program.....Rex Whitton
Simplified Push-Button Operation.....Harry McBride
Securing Surplus Property.....Cecil Jenkins
Is the Water Really There?.....Frank Austin
Analytical Reference Service and Evaluation of Results.....Harry P. Kramer
Simplified Laboratory Tests for Plant Control.....Hans Albertsen
Pipe Joints—Compression Type.....Harold Williams

Montana Section—April 28–30, 1960

Address of Welcome.....*Mayor* Carl J. Clavadetscher
Fifty Years as a Rambling Engineer in Montana.....John W. Hall
Changing Concepts in Water Pollution Control.....Ray Lawrence
Your American Water Works Association.....Lauren W. Grayson
Water Works Advancement—Panel Discussion.....*Led by* E. R. Dodge, E. R. Waldo, D. S. Thomas & Del Brick
Water Quality Management.....W. J. Wenzel
Motion Pictures: What's in It for Us?; On to the Sea

Nebraska Section—Apr. 20–21, 1960

Address of Welcome.....*Mayor* Pat Boyles
Insurance: Personnel and Equipment—Panel Discussion.....*Led by* Howard L. Fletcher, F. E. Cochran & Edward Copple
Controls for Dual Fuel Equipment.....William V. Bell
Rates and Financing of Utilities.....C. H. Hoper
Water Down the Drain—Panel Discussion.....*Led by* Robert E. Arraj, J. W. Livengood & Dick Hall
Selection of Pumping Equipment and Automatic Controls..G. T. Work & Jack Williams
Purchasing: Specifications and Procedures—Panel Discussion....*Led by* Vern Livingston, Lloyd E. Chapman & John Foster

New Jersey Section—Oct. 20–22, 1960

The Formation and History of the New Jersey Section of the American Water Works Association.....Samuel F. Newkirk Jr. & P. S. Wilson
How AWWA Can Help You Help Yourself.....James B. Corey
State Water Development Programs.....George R. Shanklin
Delivering Water From Round Valley.....Charles H. Capen
Newark's Charlotteburg Reservoir Project.....Arthur J. Simpson
Point View Reservoir Project.....Richard E. Bonyun
More Water and More Power for North Jersey.....Harold Ohland
Trends in Water Works Automation—Panel Discussion.....*Led by* James Girand
Trends in Supervisory Control of Outlying Wells and Pumping Stations.....R. L. West
Automation of a Small Filter Plant.....Warren M. Zuckert
Some Aspects of Automation for the Small Plants.....Hapgood Kipp
Marketing Functions and Responsibilities of the Instrumentation Manufacturer Serving the Water and Sanitation Industries.....Frank L. Mascitti
A Bold Approach to Modernization and a New Water Supply for East Orange, N.J. ..... Charles G. Bourgin
De Laval Automatic Diatomaceous Earth Filters.....Robert J. Bazzini
Purification of Water Containing Synthetic Detergents.....E. A. Sigworth
Distribution System Corrosion Problems.....Martin E. Flentje
Discussion.....G. E. Arnold
Subaqueous-Weed Control—Panel Discussion.....*Led by* Frank DeHooge
Chemicals Available for Aquatic-Weed Control.....Donald A. Schallock
The Application and Results Obtained With Various Aquatic Herbicides..... Roy R. Younger
Weed Control and Potable Water.....Anthony T. Leahey
Round-Table Discussion.....*Led by* Edward W. Walasyk
Motion Pictures: Fury of the Winds; Knowing Is Not Enough

New York Section—April 5–7, 1960

Address of Welcome.....John J. Burns
The Three "P's" of Speech-Making.....George E. Symons
Reaching the Public Through the Press.....William T. Brady
Management Schools and Communication Techniques.....H. E. Hudson
Monitoring, Telemetering and Remote Control of Water Supply Systems..... A. Davidson Jr.
The Economics of Modern Methods of Analyzing Water Distribution Systems..... Donald E. Stearns, Annabel L. Tong & William O. Lynch
Municipal Civil Service.....Henry J. McFarland
Valve Maintenance and Valve Records.....Edward M. Griffin
Motion Pictures: Priceless Water; The Snows of Tutupaca

New York Section—Sep. 14–16, 1960

Water Works School—Valves and Hydrants.....*Led by* George E. Symons
Horizontal Boring.....William Y. Strong
High-Accuracy Magnetic Flowmeters.....Douglas Lynch
Ground Water Hydrology.....Ralph C. Heath
Round-Table Conference.....*Led by* Harold F. Rock
Motion Picture: Water Bill, USA

North Carolina Section—Nov. 9–11, 1960

Address of Welcome.....Marshall C. Kurfees
Water & Sewer Operations in Winston-Salem During the Flying Fifty's..... Stanford E. Harris

Treatment of Water High in Detergents.....E. A. Sigworth
The Limnology of Reservoirs and Water Quality.....Charles M. Weiss
Maintaining Chlorine Residuals.....A. E. Griffin
Let's Take a Look Inside Your Pipeline System.....E. Shaw Cole
Ground Storage With Pumps For Public Water Systems.....Marsden Smith
Steel Water Storage Tanks.....J. C. Richardson
Motion Pictures: Chlorine Safety; Asbestos-Cement Pipe Water Mains

North Central Section—Sep. 21–23, 1960

Address of Welcome.....*Mayor* George J. Vavoulis
Sanitation Practices.....Ray Kaplan
Safety Practices.....C. W. Hamblin
Public Relations Practices.....Eugene R. Lambert
Certification Program for Water Works Personnel...Earl H. Ruble & George Schroepfer
Education and Training of Water Works Personnel.....
Howard J. Sowden & Carroll M. Jensen
Ground Water Pollution in the Twin-City Area....A. W. Banister & Elmer A. Huset Jr.
Water Supply in Colombia, South America.....Manuel Cardozo
Water Utility Organization.....Fred G. Thielman
Office Procedures and Records.....George F. LaRoche
Salaries for Water Works Personnel.....Bruce Boyer
Water Conservation in Minnesota.....S. A. Frellsen
Taste and Odor Conditions in the North Central Section Versus the United States.....
E. A. Sigworth
Automation in Small Water Works Operations.....Sam W. Prest
Future Demands of the Water Works Industry.....Frank C. Mirgain

Ohio Section—Oct. 26–28, 1960

Address of Welcome.....Ernest H. Stork
Water Works Distribution Problems—Panel Discussion.....*Led by* Robert Holt,
H. Augenstein, R. Irvin & J. H. Rimmer
Water Works Reminiscing.....Fred H. Waring
Water Works Billing Procedure—Panel Discussion.....Stephen Suhajcik,
Evan Thomas & J. Palmer Hays
Maintenance and Care of Hydrants, Valves, and Meters—Panel Discussion.....
Led by Sidney Frissell, George Armstrong Jr., Sol J. Wittenberg & Robert Loach
Controls and You.....Jack Williams
Your Water Works—Does it Measure Up to New Standards?
Future Demands.....Homer Knox
Fire Protection.....Joe Rutter
Hydraulic Survey.....Harold Kelley
Management.....A. V. Agnew
Water Works Budgeting and Cost Control.....W. T. Eiffert & Robert Stout
Releasing News for the Newspaper.....Gene Jordan
Unsung Heroes.....M. W. Tatlock
Unmetered Fire Lines—Panel Discussion.....*Led by* R. F. Snyder,
J. Paul Price, A. Angelotta & Jasper Avery
Operational Experiences—Municipal Versus Private Water Systems.....Leo Louis

Pacific Northwest Section—May 4–6, 1960

Address of Welcome.....*Mayor* Terry Shrunk
Utility Relocation Costs in Highway Construction.....J. E. Kirk

Water Utility Rate Structures.....Arthur C. Wilson
Value of Basic Standards in Planning the Development of Water Resources..W. A. Kunigk
Pipeline Corrosion.....John Van Bladeren
Questions and Answers for Water Works Personnel.....Roger James
Progress Report on Water Works Advancement.....Fred Merryfield & E. Jerry Allen
Artificial Ground Water Recharge.....Robert H. Russell
Well Drilling and Ground Water Development.....Paul A. Durand
The Latest Development in Chlorination.....Wilson F. Bow
Membrane Filters in Water Bacteriology.....Gilbert H. Dunstan
Test Results on Coagulant Aids.....Committee Report
Effective Management Through Organization.....Milton K. Davis
Spotlighting Your Job—Discussion.....*Led by* Patrick H. Deeney
Motion Pictures: Building Swift Dam; On to the Sea; Tomorrow's Trees; Elevated Prestressed Concrete Reservoir; What's in It for Us?; Priceless Water; The Bull Run Story

Pennsylvania Section—Jun. 14–16, 1960

Address of Welcome.....*Mayor* Joseph M. Barr
Effect of Urban Redevelopment on a Water Department..John Mauro & John A. Murphy
Water Utility Advancement Program in Pennsylvania.....John H. Murdoch Jr.
Progress Report on Stream Pollution Studies in Pennsylvania
Thermal Pollution.....G. E. Arnold
Radioactivity Pollution.....Walter A. Lyon
Occurrence of Manganese in the Allegheny River Basin
George E. Whetstone & R. B. Adams
Safety at Work—Panel Discussion.....*Led by* John Cappio, J. F. Kegebein, H. J. Borchers Jr. & Paul Burdan
Standardization of Design Procedures for Prestressed Concrete Pipe.....H. F. Kennison
Shakedown of the Torresdale Filter Plant.....John A. Dillener
Practical Use of Zeta Potential Measurement in Water Treatment.....Robert J. Baker
Unusual Cases of Copper Corrosion.....G. B. Hatch
Efficiency in Office Practice.....Walter C. Christopher
Cleaning and Relining Water Mains.....V. A. Appleyard
Meter Cleaning, Testing, and Repairing.....James W. Myers Jr.
Adequate Maintenance in the Water Plant.....K. C. Armstrong
Bacteriological Methods.....C. W. Fifield

Rocky Mountain Section—Oct. 24–26, 1960

Address of Welcome.....*Mayor* William C. Henderson
Legal Liabilities for Unsafe Water.....Glen Saunders
Optimum pH Zones.....Walter H. Fletcher
Protection of Watersheds and Reservoirs.....Jack McCullough
The Role of Chlorine in Water Treatment.....Jim Bush
Ground Water Contamination.....William Gahr
Pipe Corrosion and Its Control.....Dana Kepner
Insurance Needs of the Water Works Industry.....Harvey Wallace
What Is Adequate Fire Protection?.....V. A. Vaseen
Valves for Water Works.....Dick Seevers
Highway Legislation and Its Effect on Public Utilities—Panel Discussion.....
Led by John Krieling, A. R. Abelard, Robert Millar & Luis D. Rovira
Motion Picture: Water Bill, USA

South Dakota Section—Sep. 7–9, 1960

ddress of Welcome.....*Mayor* Theodore Wrage Sr.
evelopment and Use of Diverted Missouri River Water in South Dakota—Panel Discussion..*Led by* Charles E. Carl, M. E. Von Seggern, Raymond Lund & Herbert C. Clare
rackish-Water Conversion Program.....Melvin Mattson
tilities Communications.....Ray Jorgenson & Jack Gerken
nstallation of Water and Sewage Works Systems in a Small Town
K. E. Benson & C. T. DeNeui
lotion Pictures: Underwater Reflections; Water Bill, USA

Southeastern Section—Mar. 20–23, 1960

ddress of Welcome.....*Mayor* W. Lee Mingledorff
he Savannah Industrial and Domestic Water Supply.....R. R. Adams
alt Water Encroachment Into the Principal Artesian Aquifer in the Savannah Area, Georgia.....Harlan B. Counts
Vell and Pump Maintenance.....Paul Schweitzer
AWWA Advancement Committee Evaluation of Water Utilities—Panel Discussion.....*Led by* M. E. Henley
Priceless Water.....S. H. Painter
Supply.....William R. Wise
Treatment.....P. J. Philson
Distribution.....W. H. Weaver
Metering.....C. H. Muckenfuss
Summary.....J. B. Corey
Effects of Hurricane Gracie Upon South Carolina Water Utilities.....J. W. Logan Jr.
Water Treatment
Coagulation and Coagulant Aids.....A. P. Black
Effect of Impoundments Upon the Chemical Quality of Water.....F. A. Eidsness
Pipeline Capacities—Losses, Gains, and Maintenance—Panel Discussion.....*Led by* R. C. Kauffman, J. M. Roberts, W. D. Hudson, A. T. Storey & W. C. Bowen
Motion Pictures: What's in It for Us?; Pure Water and Public Health

Southwest Section—Oct. 16–19, 1960

Address of Welcome.....*Mayor* H. Y. Cartwright Jr.
A Century and a Quarter of Municipal Progress.....Thomas G. Rice
Water, Water, Everywhere But!.....R. E. L. Johnson
Desalination Research Progress Report.....Louis Koenig
Progress in Evaporation Control Research.....Archie M. Kahan
The Water Supply-Recreation Dilemma in our Protected Watersheds....William H. Davis
Developments in Water Treatment Practice—Panel Discussion.....*Led by* Ben L. Grimes
The Effect of Water Treatment on Main Carrying Capacity.....A. H. Ullrich
Practical Considerations in Filter Design and Operation.....I. W. Santry
Water Treatment Modifications.....Ben L. Grimes
We Have Thousands of Well Distributed Problems.....V. R. Schmidt
San Antonio's Attack on its Corrosion Problems.....Bruce E. Sasse
Tricks of the Trade.....J. D. Henry
What Size Cash Register Do I Need?.....Henry V. Aldrich
Water Meter Repair Practices.....W. J. Weems
White-Collar Tools.....Henry Wilkens
Pushbutton Water Experiences.....D. B. Dickson
Meeting the Challenge of an Exploding Population.....E. J. Umbenhauer
What's New?.....C. F. Wertz
Public Relations—Panel Discussion.....*Led by* R. L. Lawrence, James B. Corey, Jim Milligan & Johnie E. Williams

Virginia Section—Sep. 14–16, 1960

Some Water Supply Problems Associated With Manned Operations on the Moon.....
Harry N. Lowe J
Short School Committee Discussion.....W. G. Beazley & J. Ray Scriven
Accident Prevention Committee Report.....R. A. Paint
Operators Certification Program—AWWA Representative Report.....W. W. Ande
Water Utility Advancement Committee Report.....X. D. Murde
Water Supply Survey, City of Belo Horizonte, Brazil.....James A. Riv
Some Aspects of Water Supplies for New Industries.....H. P. Cotto
Teaching An Old Plant New Tricks.....M. E. Flentje & E. F. E
Solubility of Radioactive Fallout in Water.....Don C. Lindste
Tastes and Odors in Virginia Versus the Overall United States.....E. A. Sigwort
AWWA Can Help You Help Yourself.....James B. Core
Solution To A Difficult Transmission Problem.....Dennis M. Leary J
Motion Pictures: Chlorine Safety; What's in It for Us?

West Virginia Section—Mar. 24–25, 1960

Address of Welcome.....*Mayor* R. O. Ellis J
ORSANCO and Ohio River Water Quality.....F. W. Montanar
Water Cocktail on the Rocks.....C. F. Wert
Federation Activities.....W. D. Hatfiel
Why Paints Fail.....E. J. Sirma
Installation and Performance of Radial Collection Wells in Ohio River Gravels.....
H. K. Gidley & John H. Milla
Value of Water Systems in Stimulating Progress in Undeveloped Countries.....
Edmund G. Wagne
Chlorination Practices in West Virginia.....James E. Rosencranc
Exterior Corrosion of Water Lines.....Hugh W. Hetze
Reading Meters by Radio..... Weldon Walker Jr
Practical Use of Aerial Photography for Mapping New and Old Water Systems.....
W. S. Staub
Tastes and Odors in West Virginia Versus Overall United States.....E. A. Sigworth
Recent Advances in Equipment and Technique of Water Analysis.....Stephen Megregian
New Aids to Coagulation.....Christopher P. Blakeley
Motion Pictures: Highway Hearing; The Submersible Story; Made for the Earth

Wisconsin Section—Sep. 28–30, 1960

Address of Welcome.....*Mayor* Ivan A. Nestingen
Abandonment of Wells.....Thomas A. Calabresa
Water Well Stimulation.....Ernest H. Gras & Louis Koenig
Use of Polyphosphates for Iron Control.....Eugene Hensel
Radioactivity in Water and Its Removal.....H. Gladys Swope
Synthetic Detergents as a Criterion of Ground Water Pollution.....
M. Starr Nichols & Elaine Koepp
Automation and Telemetering in Water Systems.....Nate Miller
Wisconsin Utility Experience in Accounting for Unmetered Water..William A. Kuehlthau
Solving Management Problems.....Robert L. Broucek
Reasonable Return on Municipal Water Works Operations.....Preston A. Reynolds
Motion Pictures: Beaver Valley; Man in Space; Nature's Half Acre

Section Meetings—1956–1960

Section	*1956*	*1957*	*1958*	*1959*	*1960*	*Meeting Place—1960*
Alabama-Mississippi	Oct. 21–24	Oct. 20–23	Sep. 28–Oct. 1	Oct. 18–21	Oct. 9–12	Birmingham, Ala.
Arizona	Apr. 5–7	Apr. 4–6	May 15–17	Apr. 16–18	Apr. 28–30	Tucson, Ariz.
California	Apr. 13*	Apr. 26*	———	———	Apr. 22*	Monterey, Calif.
	Oct. 23–26	Oct. 29–Nov. 1	Oct. 28–31	Oct. 30	Oct. 25–27	Long Beach, Calif.
Canadian	Apr. 23–25	Jun. 17–19	Jun. 1–4	May 3–6	Apr. 24–27	Buffalo, N.Y.
	Oct. 15–16†	Oct. 17–18†	Oct. 1–3†	Sep. 9–11†	Sep. 28–30†	Charlottetown, P.E.I.
Chesapeake	Oct. 24–26	Oct. 30–Nov. 1	Oct. 29–31	Oct. 7–9	Nov. 2–4	Washington, D.C.
Connecticut	———	———	———	———	Oct. 6	Hamden, Conn.
Cuban	Nov. 29–Dec. 1	‡	———	Nov. 19–21	‡	‡
Florida	Nov. 11–14	Nov. 10–13	Oct. 19–22	Nov. 15–19	Nov. 13–16	West Palm Beach, Fla.
Illinois	Mar. 21–23	Mar. 20–22	Mar. 26–28	Mar. 11–13	Mar. 16–18	Chicago, Ill.
Indiana	Feb. 8–10	Feb. 6–8	Feb. 5–7	Feb. 4–6	Feb. 3–5	Indianapolis, Ind.
Intermountain	———	———	Nov. 6–7	Oct. 8–9	Oct. 6–7	Salt Lake City, Utah
Iowa	Oct. 24–26	Oct. 16–18	Oct. 15–17	Oct. 14–16	Oct. 19–21	Des Moines, Iowa
Kansas	Apr. 4–6	Apr. 10–12	Mar. 12–14	Apr. 22–24	Apr. 20–22	Emporia, Kan.
Kentucky-Tennessee	Sep. 17–19	Sep. 23–25	Sep. 22–24	Sep. 14–16	Sep. 12–14	Knoxville, Tenn.
Michigan	Sep. 12–14	Sep. 25–27	Sep. 8–10	Sep. 23–25	Sep. 21–23	Traverse City, Mich.
Missouri	Sep. 30–Oct. 2	Sep. 29–Oct. 1	Sep. 28–30	Sep. 27–29	Sep. 25–27	Jefferson City, Mo.
Montana	Apr. 6–7	Apr. 4–6	Mar. 20–22	Apr. 9–11	Apr. 28–30	Billings, Mont.
Nebraska	Apr. 11–13	Apr. 24–26	Apr. 16–18	Apr. 15–17	Apr. 20–22	Lincoln, Neb.
New England	———	———	———	———	———	———
New Jersey	Oct. 18–20	Oct. 24–26	Oct. 23–25	Oct. 22–24	Oct. 20–22	Atlantic City, N.J.
New York	Apr. 18–20	Apr. 10–12	Mar. 26–28	Apr. 8–10	Apr. 5–7	Binghamton, N.Y.
	Sep. 12–14	Sep. 11–13	Sep. 10–12	Sep. 16–18	Sep. 14–16	Upper Saranac Lake, N.Y.
North Carolina	Nov. 12–14	Nov. 11–13	Nov. 10–12	Nov. 9–11	Nov. 9–11	Winston-Salem, N.C.
North Central	Sep. 12–14	Sep. 25–27	Sep. 24–26	Sep. 16–18	Sep. 21–23	St. Paul, Minn.
Ohio	Sep. 19–21	Sep. 18–20	Sep. 17–19	Oct. 28–30	Oct. 26–28	Columbus, Ohio
Pacific Northwest	Apr. 26–28	May 2–4	May 15–17	Apr. 23–25	May 4–6	Portland, Ore.
Pennsylvania	Apr. 3–5	Jun. 12–14	Jun. 25–27	Jun. 3–5	Jun. 14–17	Pittsburgh, Pa.
Rocky Mountain	Nov. 26–28	Sep. 23–25	Sep. 15–17	Sep. 8–10	Oct. 24–27	Colorado Springs, Colo.
South Dakota	———	———	———	———	Sep. 7–9	Pierre, S.D.
Southeastern	Mar. 18–21	Mar. 17–19	Mar. 23–25	Apr. 5–8	Mar. 20–23	Savannah, Ga.
Southwest	Oct. 14–17	Oct. 13–16	———	Oct. 18–21	Oct. 16–19	Galveston, Tex.
Virginia	Nov. 7–9	Nov. 6–8	Nov. 5–7	Nov. 4–6	Sep. 14–16	Virginia Beach, Va.
West Virginia	Oct. 31–Nov. 2	Oct. 23–24	Oct. 23–24	Oct. 28–29	Mar. 24–25	Huntington, W.Va.
Wisconsin	Sep. 26–28	Sep. 4–6	Sep. 17–19	Sep. 9–11	Sep. 28–30	Madison, Wis.

* Regional meetings. † Maritime Branch. ‡ Meeting canceled.

Section Membership at Time of, and Total Attendance at, Section Meetings—1956–60

Section	1956		1957		1958		1959		1960	
	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance
Alabama-Mississippi	219	318	224	307	235	279	253	225	253	318
Arizona	77	156	84	234	104	170	107	260	105	280
California§	1,378	1,253	1,451	1,225	1,601	1,710	1,728	470#	1,724	1,445
Canadian§	663	816	708	500	730	922	753	910	762	778
Chesapeake	267	191	288	228	306	157	310	230	310	236
Connecticut	††	††	††	††	††	††	††	††	102	96
Cuban	52	43	62	‖	58	†	56	43	49	†
Florida	355	331	361	399	385	460	377	324	420	*
Illinois	557	468	589	474	650	509	707	811	712	604
Indiana	409	421	478	499	525	602	538	429	513	510
Intermountain	**	**	**	**	76	107	107	108	114	136
Iowa	149	220	181	282	189	289	208	277	215	302
Kansas	237	236	239	217	259	228	257	223	245	197
Kentucky-Tennessee	221	317	252	317	268	368	268	344	257	345
Michigan	435	278	471	341	505	335	528	408	530	417
Missouri	228	275	238	306	246	289	251	320	231	310
Montana	54	84	61	132	64	154	63	115	63	117
Nebraska	103	183	109	150	107	63	104	143	104	172
New England	233	†	248	†	258	†	271	†	184	†
New Jersey	463	351	505	336	531	370	543	381	554	406
New York§	851	429	882	458	884	505	923	540	937	542
North Carolina	232	326	224	305	215	*	203	335	199	326
North Central	260	157	278	177	260	199	255	181	262	202
Ohio	482	253	508	281	517	334	522	378	504	416
Pacific Northwest	438	304	507	358	500	398	481	391	473	562
Pennsylvania	516	295	558	235	560	251	566	258	586	311
Rocky Mountain	186	164	237	152	205	166	209	140	213	260
South Dakota	††	††	††	††	††	††	††	††	46	144
Southeastern	278	319	300	335	326	446	315	367	320	376
Southwest	1,086	889	1,133	784	1,113	‡	1,090	1,062	1,162	810
Virginia	207	233	213	241	216	216	214	228	215	237
West Virginia	104	126	105	195	112	201	121	194	119	207
Wisconsin	199	296	206	340	216	319	220	324	304	381

* No record of attendance.
† No regular meeting scheduled. Membership given as of dates of conferences.
‡ Regular meeting canceled. Business meeting held at annual conference.
§ Only one of section's meetings recorded here.
‖ Meeting canceled.
A one-day meeting, because the annual conference was held in San Francisco.
** Section organized in 1958.
†† Section organized in 1960.

AWWA PUBLICATIONS

Effective January 1, 1961 *

Orders should be sent to the American Water Works Association, Inc., 2 Park Ave., New York 16, N.Y. A handling charge of $1.00 will be made on all orders under $5.00 unless accompanied by remittance. All payment must be in US or Canadian funds or in AWWA Publication Discount Coupons.

BOOKS

ndex to Journal AWWA (1940–55)—This cloth-bound, 192-p. book, published in 1956, includes subject, author, and geographic indexes to the JOURNAL for the 16 years from 1940 through 1955. $4.50.

tandard Methods for the Examination of Water and Wastewater. Published jointly by AWWA, American Public Health Assn. & Water Pollution Control Federation. Cloth bound, 626 pp. Eleventh edition, 1960. $10.00.

he Quest for Pure Water—By M. N. Baker. A history of water purification from the earliest records to the 20th century. 73 illustrations, 900 references, 527 pp. 1948; 2nd printing, 1949. $5.00.

urvival and Retirement Experience With Water Works Facilities—Prepared by a joint committee of the AWWA and the Institute of Water Supply Utilities. Includes reports published in installments in JOURNAL, 1945–46, with additional material and summary tables. Cloth bound, 566 pp. 1947. $3.00.

Water Quality and Treatment—Prepared by AWWA. A comprehensive survey of water quality standards and procedures for purification, softening, and other conditioning. Completely revised and enlarged second edition. 451 pp., 1950; 2nd printing, 1951. $5.00.

MANUALS

Water Rates Manual—M1—A report of the Committee on Water Rates, as published in the March 1954 JOURNAL, plus valuable supplementary data. Paper bound, 64 pp., 1960. $1.25.

Silent Service Is Not Enough!—M2—AWWA public relations study, as published in December 1954 JOURNAL, plus appendix. Paper bound, 152 pp., 1955. $1.50.

Safety Practice for Water Utilities—M3—A manual prepared by the Committee on Safety Practices and originally published serially in the JOURNAL (July–December 1955). Paper bound, 128 pp., 1960. Price, for general sales, $1.50; to members ordering quantities of 20 or more, $1.00 per copy.

Distribution System Records—M4—A manual on distribution system records and office forms, consisting of a committee report and other material published in the February 1940 JOURNAL (formerly designated C900–40). Paper bound, 52 pp., 1956. $0.75.

Water Utility Management—M5—a manual and training course prepared by the AWWA Education Committee. Paper bound, 192 pp., 1959. Price, for general sales, $2.00; to members or schools ordering 20 or more, $1.30 per copy.

Water Meters—M6—a manual on selection, installation, testing and maintenance prepared by the AWWA Meter Committee and originally published serially in the JOURNAL (June–September 1959). Paper bound, 88 pp., 1959. $1.25.

* Listings are revised periodically.

PERIODICALS AND PAMPHLETS

Journal American Water Works Association. A monthly magazine of technical papers, discussions, news, and reports. Issued quarterly from 1914 to 1919; bimonthly from 1920 to September 1924; monthly ever since. Annual indexes are contained in the December issue of each year from 1940 on. Cumulative indexes of authors and articles grouped by topics are described on p. 1607. Subscriptions to individuals only in conjunction with AWWA membership in US, Canada, and Cuba; to individuals elsewhere, $10 per year. Single copy price (issues dated 1954 and later), 85¢; issues dated 1925–1953, 75¢; issues dated 1914–24, $1.25.

Style Manual for Journal Authors. Reprint R1011. An editorial statement specifying mechanical and style requirements for JOURNAL manuscripts and outlining publication procedure. 16 pp., 25¢.

The Story of Water Supply. A pictorial presentation designed to acquaint the junior high school student with the history, accomplishments, and workings of pub water supplies. Entertaining; instructi 16 pp., il., 15¢ (quantity prices on reques "Teaching Aids" 5¢ per copy; one fr with each 50 copies of *The Story.*

What Price Water? A booklet calling tention to the real value of public wat supply by comparing 1940 and curre prices of water and other consumer goo as well as water works costs. Fits No. envelope. 12 pp., 10¢ per copy (quanti rates on request).

Willing Water. A monthly bulletin d voted to public relations, safety, defens and other special problems. Usually 10

Your Water Supply. A conservation gui designed as an envelope stuffer for quanti distribution. Includes "how-to" inform tion on reading meters, detecting leak replacing faucet washers, saving wat generally. 12 pp., il., no charge for sing copies (quantity rates on request).

JOURNAL REPRINTS

Order by title and number, not by topic. Copies of Journal articles not available in reprint form can generally be obtained by ordering a copy of the issue in which they were published; for terms, see "Journal AWWA" in preceding "Periodicals and Pamphlets" section. Additional "Reprints Available" are listed in the Journal each month under that heading.

Administration. No. R903. Committee Report: Joint Administration of Water and Sewage Facilities. From June 1959 JOURNAL. 8 pp., 20¢.

Air conditioning. No. 263. Model Ordinance. Prepared by AWWA Committee on Water Use in Air Conditioning and Refrigeration. From December 1950 JOURNAL. 8 pp., 20¢.

Air conditioning. No. R803. Committee Report: Trends in Air-Conditioning Use and Regulation. From January 1958 JOURNAL. 22 pp., 35¢.

Annual reports. No. 246. Committee Report: Water Department Annual Reports. Includes a guide to the preparation of an annual statistical report. From August 1950 JOURNAL. 14 pp., 20¢.

Bonds. No. R906. F. H. Eastman: Me chanics of Bond Issue Campaigns. Fro September 1959 JOURNAL. 16 pp., 25¢.

Bookkeeping. No. R406. R. Newsom Simplified System of Accounts for Aver age Municipal Water Works. *With* G. J Natt: Simplified Bookkeeping System fo Small Water Companies. From January 1947 and June 1949 JOURNAL. 39 pp., 70¢

Chlorination. No. R1002. Joint Commit tee Report: Chlorine Supply and Use i Water and Sewage Treatment Plant (also covers alum supply). From Janu ary 1960 JOURNAL. 12 pp., 25¢.

Chlorination. No. R342. Joint Committe Report: Recommended Procedures in th Use of Chlorine at Water and Sewag Plants. From October 1953 JOURNAL 15 pp., 25¢.

Chlorination. No. R374. Chlorine Institute: Recommended Specifications for Stationary Chlorine Storage Installations. From November 1954 JOURNAL. 12 pp., 25¢.

Corrosion. No. R817. Eliassen, Skrinde & Davis: Experimental Performance of "Miracle" Water Conditioners. From October 1958 JOURNAL. 15 pp., 25¢.

Cross connections. No. R824. Joint Committee Report: Use of Backflow Preventers for Cross-Connection Control. From December 1958 JOURNAL. 30 pp., 45¢.

Excavation. No. R612. G. F. Sowers: Trench Excavation and Backfilling. From July 1956 JOURNAL. 9 pp., 25¢.

Extensions. No. R323. Committee Reports: Water Service for Suburban Areas (from July 1953 JOURNAL), and Water Main Extension Policy (from August 1949). 39 pp., 65¢.

Filtration. No. R611. K. W. Cosens: Design and Operation Data on Large Rapid Sand Filtration Plants in the United States and Canada. From July 1956 JOURNAL. 35 pp., 60¢.

Fluoridation. No. R628. The Fluoridation of Public Water Supplies. A statement of recommended policy and procedure approved by the AWWA Board of Directors May 29, 1949, and published in the July 1949 JOURNAL. Formerly designated AWWA B700–49. 5 pp., 20¢.

Fluoridation. No. R713. Panel Discussion: Experience in Applying Fluorides. From October 1957 JOURNAL. 40 pp., 55¢.

Fluoridation. No. R320. W. W. Land & E. K. Mosenthal. Court Decisions on Municipal Water Fluoridation. From April 1953 JOURNAL. 10 pp., 25¢.

Fluoridation. No. R819. Conway: Legal Aspects of Municipal Fluoridation. From October 1958 JOURNAL. 8 pp., 20¢.

Fluoridation. No. R907. W. T. Ingram & G. W. Moore: Fluoridation in Major Cities of the United States. From September 1959 JOURNAL. 16 pp., 25¢.

Fluoridation. No. R1006. Task Group Report: Status of Fluoridation in the United States and Canada, 1958. From March 1960 JOURNAL. 7 pp., 20¢.

Fluoridation. No. R814. Joint Discussion: Availability of Fluoridation Chemicals. *With* Staff Report: Survey of Fluoride Availability. From August 1958 JOURNAL. 10 pp., 25¢.

Ground water. No. R404. Brown: Selected Procedures for Analyzing Aquifer Test Data. From August 1953 JOURNAL. 24 pp., 40¢.

Grounding. No. 270. AWWA Policy Statement: Grounding of Electric Circuits on Water Pipe. *Also* C. F. Meyerherm: Water Works Industry's Attitude on Grounding and Stray Current Problems. From April 1944 and December 1945 JOURNALS. 4 pp., 10¢.

Hydraulics. No. R805. Committee Report: Water Hammer Allowances in Pipe Design. From March 1958 JOURNAL. 16 pp., 25¢.

Law. No. R818. Panel Discussion: Trends in Water Rights Legislation. *With* A. Wolman: A Fresh Approach to Water Law. From October 1958 JOURNAL. 18 pp., 30¢.

Operation. No. 370. Panel Discussion: Fundamentals of Water Works Operation. From October 1954 JOURNAL. 15 pp., 25¢.

Pipe, cast iron. No. 359. Historical edition of "1908 Cast-Iron Pipe Specifications." From July 1954 JOURNAL. 12 pp., 25¢.

Pipe, plastic. No. R614. W. D. Tiedeman & N. A. Milone. Effects of Plastic Pipe on Water Quality [summary of National Sanitation Foundation research report]. From August 1956 JOURNAL. 5 pp., 20¢.

Pipe, plastic. No. R703. Panel Discussion: Plastic Pipe in Water Supply Use. From April 1957 JOURNAL. 12 pp., 25¢.

Pipe, plastic. No. R821. Symposium: Plastic Pipe in Distribution Systems. From November 1958 JOURNAL. 16 pp., 25¢.

Pipe, steel. No. R601. G. E. Burnett & P. W. Lewis: New Developments in Tests of Coatings and Wrappings. From February 1956 JOURNAL. 22 pp., 35¢.

Radioactivity. No. 307. Task Group Report: Instrumentation and Methods for Testing Radioactive Contamination of Water. From July 1952 JOURNAL. 12 pp., 20¢.

Regulations. No. R802. W. C. Welmon: Service Rules and Standards for California Water Utilities [including California Public Utilities Commission Rules Governing

Water Service]. From January 1958 JOURNAL. 22 pp., 35¢.

Resources. No. R706. Committee Report (with Preamble by Abel Wolman): Basic Principles of a National Water Resources Policy. From July 1957 JOURNAL. 9 pp., 25¢.

Salaries. No. R914. Committee Report: Survey on Compensation of Water Utility Managers. From December 1959 JOURNAL. 30 pp., 45¢.

Statistics. A Survey of Operating Data for Water Works in 1955. From May 1957 JOURNAL. No. R704, 144 pp., 75¢. In combination with statistical analysis by Seidel & Baumann plus R. Porges' summary of 1955 USPHS survey of treatment facilities, from December 1957 JOURNAL—No. R722, 194 pp., $1.25. The Seidel-Baumann and Porges analyses (without the operating data survey tables)—No. R723, 50 pp., 60¢.

Statistics. No. R813. J. R. Thoman & K. H. Jenkins: Inventory of 1956 Water Supply Facilities in Communities of 25,000 and Over. From August 1958 JOURNAL. 8 pp., 20¢.

Statistics. No. R820. Task Group Report: Study of Domestic Water Use. From November 1958 JOURNAL. 12 pp., 25¢.

Storage. No. R343. Committee Report: Potable-Water Storage Reservoirs. From October 1953 JOURNAL. 11 pp., 25¢.

Synthetic detergents. No. R361. Task Group Report: Characteristics and Effects of Synthetic Detergents. From August 1954 JOURNAL. 24 pp., 60¢.

Training. No. 340. Committee Report: Status of Training Courses and Certification in the United States. From September 1953 JOURNAL. 26 pp., 40¢.

Treatment. No. R402. Revision of aeration and mixing and sedimentation chapters of *Water Quality and Treatment.* From August and September 1956 JOURNAL. 36 pp., 60¢.

Unaccounted-for water. No. R724. Committee Report: Revenue-Producing Versus Unaccounted-for Water. From December 1957 JOURNAL. 6 pp., 20¢.

Valves. No. 372. L. Paul: Selection of Valves for Water Works Service. From November 1954 JOURNAL. 20 pp., 30¢.

AWWA STANDARDS

Explanation of designation system: AWWA standard designations consist of two elements separated by a dash; e.g., B224–52T. This would designate a standard in the B200 series (dealing with softening) which was approved (or last revised) as Tentative in 1952. If this document had been made Standard (with or without revision) in 1957, the designation would have become: B224–57. When such a change in status is accompanied by no revisions, or only very minor ones, the new designation is listed, but standards bearing the earlier designation continue to be furnished by AWWA until existing stocks are exhausted.

A—Source

A100–58—AWWA Standard for Deep Wells. Approved as Tentative Apr. 30, 1945, and published in the September 1945 JOURNAL. Made Standard May 10, 1946; latest revision Jan. 26, 1958. 55 pp., 75¢.

A101–55 (ASA B58.1–1955)—American Standard for Deep Well Vertical Turbine Pumps. Adopted by AWWA and the American Standards Assn. May 11, 1955, and published in the July 1955 JOURNAL. 27 pp., 50¢. *Revision pending.*

B—Treatment

B100—Filtration

B100–53—AWWA Standard for Filtering Material. Revision of 1943 document approved as Tentative Nov. 15, 1948, and published in the March 1949 JOURNAL. Made Standard Jan. 16, 1950. Revised Jun. 2, 1953. 16 pp., 25¢.

B200—Softening

B200–53—AWWA Standard for Sodium Chloride. Approved as Tentative Jul. 6, 1949, and published in the March 1950 JOURNAL. Made Standard May 15, 1953. 10 pp., 25¢.

B201–59—AWWA Standard for Soda Ash. Approved as Tentative Oct. 15, 1951, and published in the February 1952 JOURNAL. Made Standard May 15, 1953. Latest revision Jan. 26, 1959. 6 pp., 20¢.

B202–54—AWWA Standard for Quicklime and Hydrated Lime. Approved as Tentative Sep. 9, 1952, and published in the January 1953 JOURNAL. Made Standard May 27, 1954. 14 pp., 25¢.

B250–51—AWWA Standard for Cation Exchanger Test Procedures. Revision of 1943 document approved as Tentative Dec. 31, 1948, and published in the May 1949 JOURNAL. Made Standard May 4, 1951. 28 pp., 40¢.

B300—Disinfection

B300–55—AWWA Standard for Hypochlorites. Approved as Tentative Jun. 2, 1953, and published in the October 1953 JOURNAL. Made Standard Jun. 17, 1955. 6 pp., 20¢.

B301–59—AWWA Standard for Liquid Chlorine. Approved as Tentative Oct. 17, 1957, and published in the February 1958 JOURNAL. Made Standard without revision Jan. 26, 1959. [*B301–57T current.**] 6 pp., 20¢.

B400—Coagulation

B400–53—AWWA Standard for Ammonium Sulfate. Approved as Tentative Jul. 15, 1949, and published in the November 1950 JOURNAL. Made Standard May 15, 1953. 7 pp., 20¢.

B401–53—AWWA Standard for Bauxite. Approved as Tentative Apr. 28, 1950, and published in the July 1950 JOURNAL. Made Standard May 15, 1953. 8 pp., 20¢.

B402–53—AWWA Standard for Ferrous Sulfate. Approved as Tentative May 31, 1949, and published in the October 1950 JOURNAL. Made Standard May 15, 1953. 7 pp., 20¢.

B403–58—AWWA Standard for Aluminum Sulfate. Approved as Tentative Aug. 21, 1952, and published in the November 1952 JOURNAL. Made Standard May 27, 1954. Latest revision Jan. 26, 1958. 10 pp., 25¢.

B404–58—AWWA Standard for Liquid Sodium Silicate. Approved as Tentative Aug. 5, 1955, and published in the October 1955 JOURNAL. Made Standard without revision Jan. 26, 1958. 7 pp., 20¢.

B405–60—AWWA Standard for Sodium Aluminate. Approved as Tentative Jan. 26, 1959, and published in the June 1959 JOURNAL. Made Standard May 15, 1960. 8 pp., 20¢.

B500—Scale and Corrosion Control

B500–53—AWWA Standard for Trisodium Phosphate. Approved as Tentative Apr. 3, 1950, and published in the June 1950 JOURNAL. Made Standard May 15, 1953. 6 pp., 20¢.

B501–53—AWWA Standard for Caustic Soda. Approved as Tentative Oct. 15, 1951, and published in the December 1951 JOURNAL. Made Standard May 15, 1953. 6 pp., 20¢.

B600—Taste and Odor Control

B600–53—AWWA Standard for Powdered Activated Carbon. Approved as Tentative Jul. 11, 1949, and published in the February 1951 JOURNAL. Made Standard May 15, 1953. 14 pp., 25¢.

B601–55—AWWA Standard for Sodium Pyrosulfite. Approved as Tentative Dec. 18, 1953, and published in the January 1954 JOURNAL. Made Standard without revision Jun. 17, 1955. [*B601–53T current.**] 5 pp., 20¢.

B602–59—AWWA Standard for Copper Sulfate. Approved as Tentative Sep. 15, 1957, and published in the January 1958 JOURNAL. Made Standard without revision Jan. 26, 1959. [*B602–57T current.**] 8 pp., 20¢.

B700—Prophylaxis

B701–54—AWWA Standard for Sodium Fluoride. Approved as Tentative Jul. 21, 1950, and published in the September 1950 JOURNAL. Made Standard May 27, 1954. 7 pp., 20¢. *Revision pending.*

B702–55—AWWA Standard for Sodium Silicofluoride. Approved as Tentative May 27, 1954 and published in the August 1954 JOURNAL. Made Standard Jun. 17, 1955. 6 pp., 20¢. *Revision pending.*

B703–55—AWWA Standard for Fluosilicic Acid. Approved as Tentative Jul. 30, 1954, and published in the November 1954 JOURNAL. Made Standard without revision Jun. 17, 1955. 5 pp., 20¢. *Revision pending.*

---

* See explanation of designation system, p. 1610.

C—Distribution

C100—Cast-Iron Pipe, Fittings

C100–55—AWWA Standard for Cast-Iron Pressure Fittings. The "special castings" portion of the original 1908 standards for cast-iron pipe and castings; still valid for replacing old fittings, but superseded by various American Standards (which follow) for new installations. Third edition approved as Tentative Oct. 25, 1954. Made Standard Jun. 17, 1955. 30 pp., 55¢.

C101–57 (ASA A21.1–1957)—American Standard Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe. Adopted by AWWA and the American Standards Assn. December 1939 and published in the December 1939 JOURNAL. Revised 1957. 172 pp., $1.50.

C102–53 (ASA A21.2–1953)—American Standard for Cast Iron Pit Cast Pipe for Water or Other Liquids. Adopted by AWWA and the American Standards Assn. December 1939 and published in the December 1939 JOURNAL. Latest revision Jan. 13, 1953. 23 pp., 45¢.

C104–53 (ASA A21.4–1953)—American Standard for Cement-Mortar Lining for Cast Iron Pipe and Fittings. Adopted by AWWA and the American Standards Assn. December 1939 and published in the December 1939 JOURNAL. Latest revision Jan. 13, 1953. 5 pp., 35¢.

C106–53 (ASA A21.6–1953)—American Standard for Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids. Adopted by AWWA and the American Standards Assn. Jan. 13, 1953, and published in the February 1953 JOURNAL. 20 pp., 40¢.

C108–53 (ASA A21.8–1953)—American Standard for Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids. Adopted by AWWA and the American Standards Assn. Jan. 13, 1953, and published in the February 1953 JOURNAL. 24 pp., 45¢.

C110–52 (ASA A21.10–1952)—American Standard for Short-Body Cast Iron Fittings, 3 Inch to 12 Inch, for 250-psi Water Pressure Plus Water Hammer. Adopted by AWWA and the American Standards Assn. Sep. 30, 1952, and published in the November 1952 JOURNAL. 10 pp., 35¢.

C111–53 (ASA A21.11–1953)—American Standard for a Mechanical Joint for Cast Iron Pressure Pipe and Fittings. Adopted by AWWA and the American Standards Assn. Jan. 13, 1953, and published in the April 1953 JOURNAL. 12 pp., 35¢.

C200—Steel Pipe

C201–60T—Tentative AWWA Standard for Fabricated Electrically Welded Steel Pipe. Second edition approved as Tentative May 15, 1960, and published in the November 1960 JOURNAL. 20 pp., 30¢.

C202–60T—Tentative AWWA Standard for Mill-Type Steel Water Pipe. Second edition approved as Tentative May 15, 1960, and published in the November 1960 JOURNAL. 24 pp., 40¢.

[Note: The second edition of each of the above two standards covers the entire range of sizes for the kind of pipe indicated; in the first editions, which are now superseded, C201 covered large pipe and C202 covered small pipe.]

C203–57—AWWA Standard for Coal-Tar Enamel Protective Coatings for Steel Water Pipe. Second edition, superseding *both* C203–55 and C204–55, approved Mar. 27, 1957, and published in the July 1957 JOURNAL. 28 pp., 45¢.

C205–41—AWWA Standard for Cement-Mortar Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over. Published as Tentative in the January 1940 JOURNAL and made Standard Jun. 26, 1941. 16 pp., 25¢.

C206–57—AWWA Standard for Field Welding of Steel Water Pipe Joints. Approved as Tentative Jan. 10, 1946, and published in the March 1946 JOURNAL. Made Standard Nov. 27, 1950. Latest revision Jan. 22, 1957. 12 pp., 25¢.

C207–55—AWWA Standard for Steel Pipe Flanges. Approved as Tentative May 9, 1952, and published in the October 1952 JOURNAL. Made Standard Jun. 17, 1955. 6 pp., 25¢.

---

* See explanation of designation system, p. 1610.

C208–59—AWWA Standard for Dimensions for Steel Water Pipe Fittings. Approved as Tentative Jul. 14, 1955, and published in the July 1956 JOURNAL. Made Standard Jan. 26, 1959. 12 pp., 25¢.

C300—Concrete Pipe

C300–57—AWWA Standard for Reinforced Concrete Water Pipe—Steel Cylinder Type, Not Prestressed. Approved as Tentative Dec. 11, 1947, and published in the March 1948 JOURNAL. Made Standard Jun. 13, 1952. Latest revision Jul. 19, 1957. 15 pp., 25¢.

C301–58—AWWA Standard for Reinforced Concrete Water Pipe—Steel Cylinder Type, Prestressed. Second edition approved as Tentative Jun. 17, 1955. Made Standard without revision Jan. 26, 1958. 18 pp., 30¢.

C302–57—AWWA Standard for Reinforced Concrete Water Pipe—Noncylinder Type, Not Prestressed. Approved as Tentative Sep. 4, 1951, and published in the October 1951 JOURNAL. Made Standard May 15, 1953. Latest revision Jul. 19, 1957. 16 pp., 25¢.

C400—Asbestos-Cement Pipe

C400–53T—Tentative AWWA Standard for Asbestos-Cement Water Pipe. Approved as Tentative May 15, 1953, and published in the July 1953 JOURNAL. 8 pp., 20¢. *Revision pending.*

C500—Valves and Hydrants

C500–59T—Tentative AWWA Standard for Gate Valves for Ordinary Water Works Service. Second edition approved Jan. 28, 1959, and published in the July 1959 JOURNAL. 16 pp., 25¢.

C501–41T—Tentative AWWA Standard for Sluice Gates. Approved as Tentative Jun. 26, 1941, and published in the October 1941 JOURNAL. 11 pp., 25¢.

C502–54—AWWA Standard for Fire Hydrants for Ordinary Water Works Service. Revision of 1940 document approved Mar. 16, 1953, and published in the May 1953 JOURNAL. Made Standard May 27, 1954. 12 pp., 25¢.

C503–59—AWWA Standard for Wet-Barrel Fire Hydrants for Ordinary Water Works Service. Approved as Tentative Jan. 26, 1958, and published in the August 1958 JOURNAL. Made Standard without revision Jul. 17, 1959. [*C503–58T current.**] 10 pp., 25¢. [Note: The uniform color scheme for fire hydrants, formerly designated C503–37 and printed under the same cover as C502, is now incorporated (as "Appendix B") in both C502 and the new C503.]

C504–58—AWWA Standard for Rubber-seated Butterfly Valves. Approved as Tentative May 27, 1954, and published in the September 1954 JOURNAL. Made Standard Jan. 26, 1958 (including revisions approved Sep. 16, 1957). 16 pp., 25¢.

C505–58—AWWA Standard for Metal-seated Butterfly Valves. Approved as Tentative Nov. 10, 1955, and published in the February 1956 JOURNAL. Made Standard Jan. 26, 1958 (including revisions approved Sep. 16, 1957). 16 pp., 25¢.

C600—Pipelaying

C600—54T—Tentative AWWA Standard for Installation of Cast-Iron Water Mains. Revision of 1938 document approved as Tentative Jun. 3, 1949, and published in the December 1949 JOURNAL. Revised May 27, 1954. 33 pp., 50¢.

C601–54—AWWA Standard for Disinfecting Water Mains. Revision of 1947 document approved as Tentative Mar. 6, 1953, and published in the August 1953 JOURNAL. Reprinted together with commentary, "Revised Main Disinfection Procedure," by Marshall P. Crabill. Made Standard May 27, 1954. 12 pp., 25¢.

C602–55—AWWA Standard for Cement-Mortar Lining of Water Pipelines in Place—Sizes 16 Inches and Over. Approved as Tentative May 27, 1954, and published in the October 1954 JOURNAL. Made Standard without revision Jun. 17, 1955. 8 pp., 20¢.

C700—Meters

C700–46—AWWA Standard for Cold Water Meters—Displacement Type. Published as Tentative in the December 1941 JOURNAL and made Standard May 10, 1946. 12 pp., 25¢.

* See explanation of designation system, p. 1610.

C701–47—AWWA Standard for Cold Water Meters—Current Type. Published as Tentative in the April 1946 JOURNAL and made Standard Jul. 25, 1947. 12 pp., 25¢.

C702–47—AWWA Standard for Cold Water Meters—Compound Type. Published as Tentative in the April 1946 JOURNAL and made Standard Jul. 25, 1947. 11 pp., 25¢.

C703–49—AWWA Standard for Cold Water Meters—Fire Service Type. Published as Tentative in the February 1947 JOURNAL and made Standard Jan. 18, 1949. 12 pp., 25¢.

C704–50—AWWA Standard for Cold Water Meters—Current Type—Propeller Driven. Approved as Tentative Jul. 21, 1949, and published in the August 1949 JOURNAL. Made Standard May 25, 1950. 12 pp., 25¢.

C705–60—AWWA Standard for Testing Cold-Water Meters. Published in the June 1956 issue of *Willing Water* as a committee report. Approved as Tentative Jan. 28, 1957. Made Standard without revision May 20, 1960. [*C705–57T current.**] 6 pp., 20¢.

C800—Service Lines

C800–55—AWWA Standard for Threads for Underground Service Line Fittings. Approved as Tentative Jul. 25, 1947, and published in the October 1947 JOURNAL. Made Standard Sep. 15, 1948. Revised Jan. 17, 1955. Included under same cover is "Collected Standards for Service Line Materials," a committee report. 15 pp., 25¢.

D—Storage

D100–59—AWWA Standard for Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage. Latest revision Jan. 26, 1959. Combined with AWWA D102, description of which appears below, in a single booklet. 72 pp., 80¢.

D101–53—AWWA Standard for Inspecting and Repairing Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage. Revision of 1949 document approved May 9, 1952. Combined with AWWA D102, description of which appears below, in a single booklet. Made Standard May 15, 1953. 32 pp., 50¢.

D102–55T—Tentative AWWA Standard for Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage. Approved by AWWA as Tentative May 9, 1952, and published in the August 1952 JOURNAL. Available only in combination with AWWA D100 or AWWA D101, prices of which are given above. Last revised Aug. 5, 1955. *Revision pending.*

* See explanation of designation system, p. 1610.

Subject Index

A

AASGP; *see* Association of American Soap and Glycerine Producers
Abbreviations; technical, list of, 685
ABS; *see* Acrylonitrile-butadiene-styrene; Alkyl benzene sulfonate
Accidents; *see also* Safety programs
  types and costs of, 25
Accounting; *see also* Billing
  punch card systems of, 1022
  selection of equipment for, 1021
Acids; organic; fouling of anion-exchange resins by, 875
Acrylonitrile-butadiene-styrene; uses and advantages of pipe made of, 1254
Actinomycetes; tastes and odors caused by, 901
Activated carbon; fish poison removal with, 1555
  handling and feeding of, at Chicago, 847
  taste and odor removal with, 910
Activated silica; clogging of filters by, 147
  coagulation with, 201
  manganese removal by, 225
Activated sludge; quality of sewage effluents treated with, 600
Administration; *see also* Personnel relations
  report of committee on, 529
  Winnipeg, Man., manual for, 709
Aeration; oxidation of manganese by, 1330
Aerobacter; see Bacteria (coliform)
Air conditioning; *see also* Cooling water
  demand rates for water used in, at Milwaukee, Wis., 1242
  growth and regulation of, at Omaha, Neb., 278
  special charges for water used in, 1234
Alexandria, Va.; acquisition of water system of, by Fairfax County Water Authority, 825
Algae; *see* Aquatic organisms and growths
Alkalinity; carbonate; determination of, 259
  control of, for carbonate coating development, 1391
  reduction of, by accumulated lime slurry, 106
  tests of, during low-temperature lime-slaking tests, 1191
  US Public Health Service recommended limit on, 296
Alkyd resins; steel tank coating with, 1381
Alkyl aryl sulfonate; effects of ingestion of, 787
Alkyl benzene sulfonate; concentrations of, in Illinois streams, 471
  inclusion of limit on, in revised US Public Health Service Drinking Water Standards, 1354
  influence of, on viability of coliform bacteria, 1360
  Ohio River monitoring for, 607
  persistence of, in water supplies, 604
  quantitative methods for determination of, 1354
  studies of oral toxicity of, 786
Alpha particles; *see* Radiation (ionizing)
Alum; clogging of filters by, 655
  effect of phosphates on coagulation with, 1307
  electron microscope studies on coagulant action of, 500
  fluoride production with, from fluorspar, 98
  inefficiency of coagulation with, to remove fish poisons, 1560
  liquid; elimination of feeding troubles with, 847
  manganese removal by, 225
  recovery and reuse of, 857
  supply and use of, 135
  turbidity removal with, in high-rate filtration, 207
  use of, in coagulation with sodium aluminate, 856
Aluminon; aluminum determination with, 779
Aluminum; evaluation of methods for determination of, 118
  modified aluminon method for determination of, 779
Amebas; description and ecology of, 1525
  survey of, in municipal supplies, 613
American Association of State Highway Officials; standards of, for control of access to interstate rights-of-way, 1404
Ames, Iowa; studies on turbidimetric control of filter effluents at, 1411
American Water Works Association; advancement program; objectives of, 1122
  annual conference—Bal Harbour, Fla., 1581
  audit of funds; report of, 545
  awards; individual, 1583, 1586

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814
Jul. 815–958; Aug. 959–1084; Sep. 1085–1224; Oct. 1225–1342; Nov. 1342–1486; Dec. 1487–1640

AWWA; awards (*contd.*); safety, 1586
section membership; standings for, 551
committee reports and activities; aims and objectives, 1119
alum supply and use, 135
artificial ground water recharge, 1220, 1315
Bal Harbour conference (personnel), 1581
biologic infestations, 1081
chlorine supply and use, 125
corrosion of copper, 1033
cross-connections, 46
fluoridation materials and methods, 301, 1513
joint; uniformity of methods of water examination, 1072
main extension policy, 1006
meters, 1133
research needs, 1111
underground waste disposal and control, 1211
waste disposal and ground water contamination, 619
water rates, 1228
water utility advancement, 541
water works administration, 529
water works practice, 535
Connecticut Section; organization of, 708
Constitution and Bylaws; proposed revision of, 393
Journal; space devoted to research in, 1109
membership statistics for, 552
meter manual (M6) available, 87
past-president (Lauren W. Grayson); address by, 1
picture of, *July cover*
president (C. F. Wertz); pictures of, *July cover, facing p. 553*
publications; discount system for, 40
list of, 1607
report on, 520
section meeting programs and attendance, 1593
South Dakota Section; organization of, 708
standards; fabricated steel pipe (C201), 1447
mill-type steel pipe (C202), 1465
positive-displacement meters; revision of, 1133
prestressed concrete cylinder pipe (C301); design requirements of, 1397
style manual for authors, 671
Ammonia; handling and feeding of, at Chicago, 850
Analyzers; network; data and records needed in use of, 280
use of analog computers as, 313
Animas River; human radiation exposure on, 1271
Annelids; description and ecology of, 1537
Anthracite; evaluation of, as filter medium, 209
Apparatus; *see* Equipment
Aquatic organisms and growths; actinomycetes; tastes and odors caused by, 901
algae; occurrence of, in South Central United States, 898
toxic; outbreak of fish and animal poisoning by, 906
animal; operators' identification guide to, 1521
bacteria; removal of iron and maganese by, 1327
Clonothrix putealis; concentration of iron and manganese by, 1335
detection and control of, 906, 1081
occurrence of, in filtered water, 1522
plankton; filter troubles caused by, 139
resistance of, to treatment, 603
study of, in the South Central United States, 897
treatment plant problems caused by, 902
Aquifers; *see also* Ground water; Recharge
artesian; hydraulics of wells in, 1438
factors affecting waste movement in, 980
interpretation of boundary effects in, 356
Architecture; principles of, for water utility structures, 180
Arkansas; artificial-recharge studies in, 1487
Arsenic; radioactive; significance of, in Pasco, Wash., supply, 839
US Public Health Service limit on, 291
Asbestos-cement pipe; performance of, in Detroit, Mich., 1049
Asellus; description and ecology of, 1541
Asiatic clams; description and ecology of, 1547
Association of American Soap and Glycerine Producers; report of, on alkyl benzene sulfonate toxicity studies, 786
Attorneys; contract; qualifications of, 174
Authorities; *see also* Districts
Fairfax County, Va.; organization and problems of, 823
Florida flood and conservation; activities of, 975
merits of, 827
Puerto Rico; organization and operation of, 6

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Automatic equipment; *see* Equipment (control)
Aztec, N.M.; study of radioisotopes in water supply of, 1284

B

Backflow preventers; types and use of, for cross-connection control, 39, 41
Backwashing; hydraulics of flow during, 952
US and European practice in, 202
use of raw water for, 656
Bacteria; *see also* Membrane filters
coliform; differentiation of, 1577
estimation of population of, from MPN's, 807
influence of ABS on viability of, 1360
significance of, as indicators of pollution, 1577
state regulations concerning numbers of, in water, 1419
survival times of, 1577
US Public Health Service recommendations on numbers of, in water, 1419
effects of hexadecanol on, 797
iron; oxidation of iron and manganese by, 867, 1335
pathogenic; adequacy of conventional methods for detection and removal of, 600
ingestion of, by nematodes, 616
removal of iron and manganese by, 1327
Bal Harbour, Fla.; photo of Americana Hotel at, *April cover*
Baltimore, Md.; control of unaccounted-for water at, 442
Barium; US Public Health Service prohibiton on, 293
Bathophenanthroline; determination of ferrous iron with, 1567
Beaver Falls, Pa.; taste and odor control studies at, 505
Beetles; diving; description and ecology of, 1544
whirligig; description and ecology of, 1545
Bel Air, Md.; use of fluorspar for fluoridation at, 98
Beta particles; *see* Radiation (ionizing)
Billing; customer complaints concerning, 425
machine; considerations in adoption of, 1024
selection of equipment for, 1021
Bloodworms; description and ecology of, 1542
Bonds; *see also* Financing
Wisconsin regulations for financing with, 165
Bookkeeping; *see* Accounting; Billing
Booster pumps; *see* Pumps
Bosmina; description and ecology of, 1539
Brackish water; *see* Saline-water conversion; Sea water
Breaks; *see* Pipe; Pipelines; Water hammer
Brine; cleanup of fouled anion-exchange resins by treatment with, 880
Bronze; replacement of, in meter manufacture, 53
Bryozoa (moss animals); description and ecology of, 1535
Budgets; importance of, in fiscal planning, 1125
Buildings; *see* Architecture
Butyrate; uses and advantages of pipe made of, 1255

C

Cadmium; evaluation of methods for determination of, 119
need for limit on, 297
studies of chronic toxicity of, 651
Calcination; techniques and economics of, for lime recovery, 322
Calcite; *see* Carbonate
Calcium carbonate; *see also* Softening
calculation of saturation index for, 1265
clogging of filter underdrains by, 655
effect of flow velocity on stabilization of, 1264, 1266
momentary excess of, as measure of supersaturation, 729
Calcium fluoride; *see* Fluoridation
California; *see* Coalinga; East Bay Municipal Utility District; Los Angeles; Sacramento
artificial recharge in, 1221
Canada; *see also* Ontario Water Resources Commission
progress of water research in, 1099
status of fluoridation in, 301, 1513
Carbon; activated; handling and feeding of, 847
taste and odor control with, 910
Carbon filters; *see also* Solvent extraction
extraction of organic pollutants with, 1364
proposed use of, for monitoring water quality, 690
Carbon dioxide; aggressiveness of, in artesian waters, 1445

Carbonate; clogging of lime feed lines by, 850
deposition of, in artesian wells, 1446
formation of anticorrosion coatings by, 721, 1386
Cast-iron pipe; causes and prevention of breaks in, 1045
effects of soil corrosion on, 638
failures of, in Detroit, Mich., 1050
Chain of Rocks, Mo.; early lime-slaking experiments at, 1189
Charges; service connection; Dallas, Tex., policy on, 1008
special; for imposition of heavy loads, 1234
Chemicals; handling and feeding of, at Chicago, 847
Chicago, Ill.; chemical handling and feeding at, 847
evaluation of MPN indexes at, 804
Chironomid worms; description and ecology of, 1542
Chloride; US Public Health Service recommended limit on, 295
Chlorination; disadvantages of, for small supplies, 247
importance of, to control iron bacteria, 868
increases in use of, in United States, 1416
influence of, on manganese oxidation, 221
state regulation of practices in, 1421
status of practice of, in Kansas, 888
tastes and odor control by, 507
Chlorine; algae control with, 909
evaluation of fish poison removal with, 1557
feeding and handling difficulties with, 895
liquid; determination of impurities in, 1338
oxidation of manganese by, 1330
residual; frequency of tests for, 1423
value and use of, in distribution systems, 890
supply and use of, 125
US Public Health Service recommendations on, 1421, 1423
Chlorine dioxide; evaluation of oxidation of fish poisons with, 1559
oxidation of manganese by, 1331
Chloroform; extraction of sulfates and sulfonates by, 474
Chloroform-soluble carbon filter extract; proposed use of, for monitoring water quality, 690
use of, to assay organic pollution, 1364
Chromium; evaluation of methods for determination of, 119
hexavalent; US Public Health Service limit on, 292
studies of chronic toxicity of, 651
Ciliates; protozoan; description and ecology of, 1525
Clams; Asiatic; description and ecology of, 1547
infestations of raw-water lines by, 1084
Cleveland, Ohio; internal conduit repairs at, 437
Clonothrix putealis; concentration of manganese and iron by, 1335
Coagulation; advances in techniques of, 201
alum; inefficacy of, in removal of fish poisons, 1560
basic mechanisms of, 492
effects of phosphates on, 1303
manganese removal by, 225
polyelectrolyte aids; current use of, 201
effectiveness of, on Lake Michigan water, 150
properties of, 497
US Public Health Service reports on, 152, 441, 969, 1415
Shreveport, La., transfer line improvements in basins for, 461
Coagulation; surfactants as aids in, 503
use of sodium aluminate for, 852
Coalinga, Calif.; saline-water conversion plant at, 585
Coatings; tank; metallic sprays for, 192
resins for, 1380
Cold-weather operation; occurrence of main breaks during, 1041
thawing of services in, 288
Coliform index; adequacy of, for detecting pathogenic bacteria, 600
Colloids; properties of, 492
Colorado; *see* Denver; Durango
Columbia River; removal of radionuclides from water of, by conventional treatment, 834
Computers; *see also* Analyzers
digital; application of, to filter studies, 933
types and applications of, 311
Concrete; prestressed; use of, for storage facilities, 373
Concrete pipe; creep strain as factor in design of, 1400
prestressed; relaxation of steel reinforcement wire in, 1399
standardization of design procedures for, 1397
types and uses of, 1244

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Condemnation; authority acquisition of a privately owned utility by, 827
Conductivity; underground corrosion related to, 378
Conduits; *see* Pipelines
Connecticut; organization of AWWA section in, 708
Conservation; ground water; High Plains of Texas, 1491
Nassau County, N.Y., 1495
industrial water; Kingston, N.Y., practices in, 175
water resources; artificial recharge for, 1315
Everglades areas reserved for, 747
federal Water Supply Act provisions for, 829
New Jersey program for, 594
Construction; development and execution of contracts for, 170
establishment of work standards for, 699
long-range planning for, 13
pipeline; good practices in, 1043
use of hydraulic jacks in, 273
prestressed-concrete tanks, 375
reservoir; Army Corps of Engineers activities in, 830
sealing of concrete joints in, 930
Consultants; engineering; role of, in planning utility construction, 171
utilization of, in preparation for bond hearings, 1016
Consumption; forecasts of, for stream dilution, 967
irrigation; in Florida, 971
reduction of, through metering, 435
Contractors; role of, in development and execution of construction contracts, 173
Cooling water; reactor; Hanford Atomic Products Operation, Wash.; 834
seasonal use of ground water for, 1317
Copper; evaluation of methods for determination of, 120
manganese oxidation aided with, 1331
studies of corrosion of, 1033
taste threshold concentration of, 666
US Public Health Service recommended limit on, 293
Copper-base alloys; replacement of, in meter manufacture, 53
Copper sulfate; use of, as an algicide, 908
Corrosion; cast-iron pipe; effects of soil on, 638
factors involved in inhibition of, 1264
Corrosion (*contd.*); fluoride-feeding equipment; problem of, 848
hot-water; apparatus for tests of, 1142
pipe; carbonate deposits for protection against, 721
losses in carrying capacity caused by, 1263
protection against, in artesian wells, 1446
tank; use of cathodic protection against, 192
underground; relationship of soil conductivity to, 378
well casing; effect of, on discharge, 1444
Costs; alum sludge recovery, 864
coagulation, 855
Dallas, Tex., water and sewer system, 1011
distribution; reduction of, through metering, 435
filtration; influence of short runs on, 147
flood control; in Everglades, Fla., 747
intakes, 96
lime recovery, 325, 331
main extension, 1006
pasteurization unit for small supplies, 253
phosphate storage and handling, 1196
pipeline; saving in, through recharge, 1317
porous-plate underdrains, 658
protective pipeline coating development, 1389
recharge water treatment, 1375
saline-water conversion, 564, 585, 592, 990, 1004
solar distillation, 1004
steel plate; differences in, 1139
submersible pumps; 1151
treatment; reductions in, by proper controls, 1320
treatment plant, at Midland, Mich., 455
water service; classes of, 1229
water supply development; trends in, 155
water utility structures, 180
well stimulation, 631, 1499
work evaluation program, 706
Coumarone-Indene resins; properties of, 1384
Council Bluffs, Iowa; studies of coagulation at, 852
Couplings; *see* Fittings; Pipe joints
Crenothrix; control of infestations of, 1081
studies on, 915
Cross connections; hazards and control of, 36, 41
report ofcommittee on (referred to), 46
Crustaceans; control of, in distribution systems, 1083
description and ecology of, 1541

CSCFE; *see* Chloroform-soluble carbon filter extract
Current ratio; use of, in evaluating financial stability, 165
Customers; *see* Public relations
Cyanide; need for limit on, 297
Cyclops; control of infestations of, 1081
description and ecology of, 1540

D

Dallas, Tex.; main extension policy at, 1006
Dams; diversion; collapsible rubber fabric used for, 1373
navigation; Ohio River program of, 1208
Daphnia; description and ecology of, 1539
Daytona Beach, Fla.; solar-distillation plant at, 555, 583
Deionization; *see* Ion-exchange; Resins; Saline-water conversion
Delaware; *see* Newark
Delhi, India; hepatitis epidemic at, 687
Demand; national growth of, 959
planning of storage to meet fluctuations in, 714
Demineralization; *see* Ion-exchange; Saline-water conversion
Denver, Colo.; bond issue campaigns at, 1015
saline-water conversion studies at, 563
Depreciation; effect of inadequate charges for, 818
significance of, in utility financing, 164
Desalinization; *see* Saline-water conversion
Design; automatic rubber diversion dam, 1375
coagulation basin; improvements in, 461
distribution piping; valve installation in, 1341
elevated-tank; choice of steel plate in, 1139
filter underdrains, 656
Hammond, Ind., distribution system, 1059
intakes, 88
low-temperature liquid lime slakers, 1189
prestressed concrete cylinder pipe; standardization of procedures for, 1397
steel pipe; uses of high-tensile steel in, 1137
water utility structure; architectural treatment in, 180
Des Moines, Iowa; financing methods at, 154
Detergents; *see* Synthetic detergents
Detroit, Mich.; experience with main breaks at, 1048
Developers; real estate; refunds of extension charges to, 1007
Development; water resources; limitations of available supply for, 965
Florida Everglades activities in, 742
New Jersey activities in, 594
water service; advance planning necessary for, 153
water supply; Midland, Mich.; description of, 449
Oakland County, Mich.; description of, 429
Diatomaceous earth; potable-water treatment by filtration with, 203
Dilution; effect of, on radioisotope concentrations in Animas River, 1279
reduction of stream pollution by, 1349
Diplogaster nudicapitatus; description and ecology of, 1533
Disease; hepatitis; Delhi, India, epidemic of, 687
waterborne; Kansas outbreaks of, 888
role of bacterial pollution in, 1352
Disinfection; state standards for, 1420
study of practices in, in the United States, 1416
US Public Health Service recommendations on, 1419
Distillation; saline-water conversion by, 554, 574, 985
Distribution systems; adequacy of, for fire protection, 413
Hammond, Ind.; design and operation of, 1059
mapping of, by aerial photography, 1129
placement of storage in, 714
planning of; records needed for, 280
problem of infestations in, 904
District of Columbia; control of unaccounted-for water in, 446
Districts; conservation; Florida Everglades, 973
High Plains of Texas, 1492
desirability of, for water supply planning and financing, 832
flood control; Florida Everglades, 973
Oakland County, Mich.; organization and operation of, 426
Dividends; payment of, by utilities, 165
Driving-force index; use of, in studies of carbonate deposition, 729, 1387
Durango, Colo.; uranium production and waste disposal at, 1271
Dysentery; waterborne; Newton, Kan., epidemic of, 888
prevalence of, 1352

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

E

East Bay Municipal Utility District, Calif.; establishment of work standards by, 699
Electrodialysis; properties of membranes for, 556
saline-water conversion by, 555, 986
Electrolysis; stray-current; effect of, on pipe corrosion, 1042
Electrophoresis; application of, to waste treatment, 503
Emergencies; planning distribution storage for, 717
Employees; *see* Personnel relations
Engineers; *see* Consultants
Epoxy resins; steel tank coating with, 1382
Equipment; alum recovery, 862
billing and accounting; selection of, 1021
chemical handling and feeding; fluoride, 848
fluorspar; design and operation of, 99
innovations in, at Philadelphia, Pa., 1196
chlorination; Kansas survey of, 893
state regulation of, 1424
control (automatic and remote); distribution system, in planning storage, 718
treatment plant, at Midland, Mich, 460
corrosion test; description of, 1142
demand metering; use of, at Milwaukee, Wis., 1240
field; for chloride determination in ground water, 923
filter effluent sampling, 1083
flocculation; use of turbine agitators for, 201
fluoride feeding, 848
fluorspar feeding; design and operation of, 99
infiltration rate measurement, 751
laboratory; iodide determination, 920
leak detection; British research on, 1094
lime recovery; types and operation of, 323
low-level turbidimeter, 1411
river stage recording, 739
saline-water conversion, 556, 587, 993
solar distillation; improved design of, 993
spreading-basin cleaning, 1375
submersible pumps; types and operation of, 1145
turbidity measurement, 1320, 1411
well drilling, rotary, *March cover*, 351
Escherichia coli; *see* Bacteria (coliform)
Evaporation; *see* Distillation
Everglades, Fla.; flood control and water management in, 742, 973
Extensions; Dallas, Tex., policy on, 1006
economic principles of sound policies on, 815
sizing of facilities for, 821

F

Fairfax County Water Authority, Va.; organization and problems of, 823
Fallout; *see* Radioactivity
Feeding; chemical; Chicago experiences in, 847
fluoride, 848
fluorspar, 99
Fergus Falls, Minn.; bond issue campaign at, 1015
Ferric chloride; effect of phosphates on coagulation with, 1311
Ferric sulfate; effect of phosphates on coagulation with, 1311
manganese removal by, 225
Ferrous sulfate; handling and feeding of, at Chicago, 847
Filter media; theory of flow in, 941
Filters; biologic sampling of effluents from, 1083
conditioning and cleaning of, 1320
developments in operation and washing of, 202
effect of manganese on, 1328
factors affecting head losses in, 949
polyelectrolytes for control of breakthrough in, 207
porous-plate underdrains for, 653
sand grain growth in, due to manganese dioxide, 1580
study of short runs with, 137
test program for evaluation of, 205
turbidimetric control of effluents from, 1411
turbidity removal with, 1321
two-layer beds for, 215
Filtration; diatomaceous-earth; potable-water treatment with, 203
high-rate; chemical treatment and control in, 1323
selection of media for, 1324
simulation of, on a digital computer, 933
study of short runs in, 137
Financing; bond; Michigan regulations of, 427
Wisconsin practices in, 165
main extension, 815, 1006
planning and methods of, 154
Puerto Rico Aqueduct and Sewer Authority; methods of, 10

Financing (*contd.*); water storage; federal Water Supply Act provisions on, 830
West Virginia methods for, 308
Fire prevention; importance of, in safety programs, 33
Fire protection; analysis of flow for, at Hammond, Ind., 1065
consideration of, in planning distribution storage, 716
establishment of charges for, 1233
extension policies affected by, 821
surveys of facilities for, 413
valve-operating procedures for, 1070
Fish; consumption of hexadecanol by, 793
Fish poisons; chemical stability of, 1560
study of toxicity and removal of, 1551
Fittings; concrete pipe, 1249
meter; evaluation of plastics for, 53
pipeline; thrust blocks used with, 81
Fleas; *see* Water fleas
Flocculation; *see also* Coagulation
turbine agitator equipment for, 201
Flood control; Florida projects for, 742, 973
Floods; US Geological Survey reports on, 738
Florida; *see also* Bal Harbour; Daytona Beach; Everglades; Gainesville; Miami; Tampa
salt water intrusion in, 1222
water resources and conservation in, 970
Flow; distribution system; Hammond, Ind., analysis of, 1061
filter; theory of, 941
pipe; corrosion affected by rate of, 727, 731
effect of, on carbonate deposition, 1266, 1387
stream; influence of variations in, on radionuclide content, 839
program of data collection on, 735
underground; effect of various factors on, 980
Fluorescein; use of, as ground water tracer, 753
Fluoridation; fluorspar (calcium fluoride) used in, 97
status of, in the United States and Canada, 301, 1513
Fluoride; feeding of, at Chicago, 848
statistical evaluation of test results for, 466
US Public Health Service limit on, 290
Fluorocarbons; use of, as pipe material, 1255
Fluorspar; use of, for fluoridation, 97
Fluosilicic acid; feeding of, at Chicago, 848
studies on toxicity and decomposition of, 927
Freezing; *see also* Cold-weather operation
conversion of saline water by, 555, 568, 986
Friction; pipe; calculation of losses due to, 946

G

Gainesville, Fla.; lime recovery plant at, 325
Gamma radiation; biologic effects of various doses of, 842
Gas hydrate separation; conversion of saline water by, 987
Gate valves; installation and maintenance of, at St. Paul, 269
Government; *see also* Legislation and regulation
Great Britain; participation of, in water research, 1087
US; Army Corps of Engineers; water storage included in projects of, 830
Atomic Energy Commission; distribution of radioisotopes by, 843
Bureau of Census tracts; usefulness of, in system planning, 281
Bureau of Reclamation; inclusion of water supply storage in projects of, 830
effect of highway legislation of, on utilities, 1404
Geological Survey; streamflow data program of, 735
Office of Saline Water; research activities of, 553, 984
Public Health Service; Analytical Reference Service report of, 117
proposed revision of Drinking Water Standards of, 1160, 1165
resources data collection activities of, 831
significance of chemical limits in standards of, 289
water research grants of, 1107, 1117
Senate Select Committee on National Water Resources; activities of, 965
Gravel; filter; theory of flow in, 941
Grand Prairie, Ark.; artificial-recharge studies in, 1487
Great Britain; progress of water research in, 1085
Green Swamp, Fla.; water control in, 975
Ground water; *see also* Aquifers; Recharge; Wells
ABS contamination of, 1355

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Ground water (*contd.*); artesian; daily discharges of, in central Florida, 972
effects of underground waste disposal on, 979
Illinois; natural radioactivity in, 769
iodide used as indicator of brine contamination in, 919
Newark, Del., studies of, 749
movement of, in Walla Walla Basin (Wash.), 1428
Ohio River gravel; mineral content of, 1207
recharge used to combat decline in levels of, 1316
seasonal use of, for cooling water, 1317
survey of contamination of, in various states, 1211

H

Half-life; isotopic composition of reactor effluents affected by, 836
relative hazard of radioactive materials, affected by, 843
Hammond, Ind.; distribution system design and operation at, 1059
Handling; chemical; use of multipurpose bins for, 1195
Hanford, Wash.; filter evaluation program at, 205, 1319
radioactive-waste treatment and disposal at, 834
Hardness; *see* Alkalinity
Health; public; formation of standards for, 1343
relationship of plumbing to, 190
relationship of taste and odor to, 1366
Health hazards; radiologic; estimation of, on Animas River, 1271
ionizing radiation as, 841
need for standards for control of, 1344
reclaimed water as, 600
Hepatitis; epidemic of, at Delhi, India, 687
Hexadecanol; effects of, on Lake Hefner, Okla., water quality, 791
High Plains Underground Water Conservation District, Tex.; artificial-recharge tests in, 1491
Highways; federal-aid; utility right-of-way and access in, 1404
Hillsborough River; quality variations in, 857
Howard Bend, Mo.; low-temperature liquid lime slaking at, 1189
Hydra; description and ecology of, 1528
Hydrants; maintenance of, at La Crosse, Wis., 286
Hydraulic fracturing; well stimulation by, 338
Hydraulics; aquifer; analysis of, in artesian wells, 1438
considerations in, 980
filtration; formulas and terminology used in, 957
studies of, 933, 940
pipeline; effect of valve operation on, 65
Hydrogen sulfide; aggressiveness of, in artesian waters, 1445
Hydroxide; iron and manganese; clogging of filter underdrains by, 655

I

Idaho; *see* Idaho Falls
Idaho Falls; comparison of metered and unmetered systems at, 433
Illinois; *see also* Chicago; Rosiclare
artificial-recharge operations in, 1221
natural radioactivity in water resources of, 769
phosphate and alkyl benzene sulfonate concentrations in streams of, 471
water research activities in, 1114
India; *see* Delhi
Indiana; *see also* Hammond; Indianapolis; Richmond
cross-connection regulation in, 35
Indianapolis, Ind.; pipeline failures in, 1051
Industrial wastes; effect of, on stream quality, 1349
Industrial water; conservation and use of, at Kingston, N.Y., 175
consideration of requirements for, in quality standards, 1177
Infestations; questions and answers on, 1081
Infiltration rates; determination of, 751
Information agencies; water research, in Great Britain, 1096
Injection; *see* Recharge
Insecticides; study of toxicity and removal of, 1551
Insects; *see* Beetles; Water bugs
Intakes; design and installation of, 88
screens for, 95
Investment; *see* Financing
Iodide; suggested method for determination of, 919
Ion exchange; *see also* Resins
removal of radioactivity by, 845
Ionization; radiation damage caused by, 841

Iowa; *see* Ames; Council Bluffs; Des Moines
Iron; evaluation of methods for determination of, 121
ferrous; determination of, in presence of ferric iron, 1567
microbial concentration of, 1335
oxidation of, by bacteria, 867
taste threshold concentration of, 667
US Public Health Service recommended limit on, 294
Isotopes; *see* Radioisotopes

J

Jacks; hydraulic; pipeline installation by use of, 273
Jellyfish; fresh-water; description and ecology of, *December cover*, 1529
Jersey City, N.J.; first use of chlorinated lime for disinfection at, 1416
Joints; *see also* Pipe joints
concrete reservoir; sealing of, 930

K

Kalamazoo, Mich.; recharge experiments at, 1223
Kentucky; *see* Louisville
Kingston, N.Y.; industrial water use and conservation at, 175

L

Labor; *see* Personnel relations
Laboratory methods; aluminum determination, 779
colorimetric determination of selenium, 1199
evaluation of, for analysis of heavy metals, 117
dissolved-oxygen determination, 1575
ferrous-iron determination, 1567
identification of nematodes, 695
silicon tetrachloride determination, in liquid chlorine, 1338
La Crosse, Wis.; valve and hydrant maintenance at, 286
Lake Hefner; effects of hexadecanol on quality of, 791
Lake Michigan; natural radioactivity in, 776
polyelectrolyte aids in coagulation of water from, 150
study of short filter runs with water from, 137
Lake Okeechobee, Fla.; role of, in Everglades history, 742
Langelier index; inadequacy of, as measure of corrosiveness of water, 727
Lansing, Mich.; well pumps used at, 1145
Lawrence, Mass.; evaluation of MPN indexes at, 804.
plumbing research program at, 190
water research activities at, 1103
Lead; evaluation of methods for determination of, 121
US Public Health Service limit on, 289
Leaks; *see also* Unaccounted-for water
detection of; Baltimore, Md., program for, 442
British research on, 1094
Legislation and regulation; federal; saline-water conversion, 984, 987
water supply projects, 829
ground water pollution control; trends in, 622
ground water recharge, 1220
public health; role of drinking water standards in, 1181
state; ground water resources, 1496
minimum standards for public water supplies, 1418
Virginia; authority organization, 824
well construction practice; need for, 1218
Wisconsin; utility earnings, 162
Liability; doctrine of implied warranty in determination of, 1185
drinking water standards in determination of, 1183
judicial concepts of, 19
Lime; handling and feeding problems with, at Chicago, 850
liquid; low-temperature slaking of, 1189
oxidation of manganese by, 1332
recovery of, by recalcination, 323
US Public Health Service recommended limit on, 293
Litigation; fluoridation; trends in, 1182
utility liability; use of drinking water standards in determination of, 1183
Load; effect of variations in, on utility investment costs, 817
Long Island, N.Y.; artificial-recharge practices in, 1222
Los Angeles, Calif.; automatic rubber diversion dam at, *November cover*, 1373
safety program at, 33
studies of recharge of reclaimed water at, 1222
Louisiana; *see* Shreveport
Louisville, Ky.; water supply financing at, 155

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

M

Magnesium; reduction of, by accumulated lime slurry, 106
US Public Health Service recommended limit on, 294
Mains; *see also* Distribution systems; Pipe
dead-end; cleaning of, by recirculation, 1060
utility liability for damage from breaks in, 20
Maintenance; costs of, 157, 181
establishment of work standards for, 699
gate valves, 272
meter; control of unaccounted-for water by, 447
tank, 191
valve, at La Crosse, Wis., 286
Management; functions and duties of, 709, 1122
Manganese; bacterial oxidation of, 867
evaluation of methods for determination of, 123
microbial concentration of, 1335
removal of, 219, 1326, 1330
stabilization of, 867, 1328
taste threshold concentration of, 668
US Public Health Service recommended limit on, 294
Manganese dioxide; filter sand grain growth caused by, 1580
Manholes; valve; design of, 271, 285
Manitoba; *see* Winnipeg
Manuscripts; rules of preparation of, for *Journal AWWA*, 673
Maps; distribution system; use of aerial photography in preparation of, 1129
Marinette, Wis.; thawing of services at, 287
Maryland; *see* Baltimore; Bel Air
Massachusetts; *see also* Lawrence
ground water contamination in, 1214
Membrane filters; comparison of media for, 232, 245
evaluation of, for water quality monitoring, 229
interpretation of results with, 244
Meramec River; water main crossing on, *January cover*, 76
studies on magnesium reduction in, 106
Metals; taste threshold concentrations of, 660
Metaphosphate; control of carbonate deposits by, 725
Metering; advantages of, 432, 1225
demand; desirability of, for establishing equitable rate structures, 1231
use of, at Milwaukee, Wis., 1239
Meters; materials to replace copper-base alloys in, 53
positive-displacement; progress in revision of standard for, 1133
Methemoglobinemia; nitrate in drinking water as cause of, 298
Miami, Fla.; lime recovery plant at, 326
problems of waste water injection at, 982
Michigan; *see also* Detroit; Kalamazoo; Lansing; Midland; Monroe; Oakland County Department of Public Works
ground water contamination in, 1214
liability litigation in, 20
Microphotometer; turbidity measurement with, 206, 211
Midges; *see* Chironomid worms
Midland, Mich.; design and operation of treatment plant at, 449
Milwaukee, Wis.; recharge experiments at, 1223
Minnesota; *see also* Fergus Falls; St. Paul
ground water contamination in, 1216
Missouri; *see also* Chain of Rocks; Howard Bend; St. Louis
ground water contamination in, 1215
Missouri River; studies of organic pollution in, 1364
Monobeds; anion-exchange; performance of, in presence of organic foulants, 876
Monroe, Mich.; survey of environmental radioactivity at, 1291
Most probable number; *see* MPN indexes
MPN indexes; analysis of variance in, 807
membrane filter technique compared to, 229
reliability of, for estimating coliform bacteria, 803
Multiple-treatment units; design and operation of, at Midland, Mich., 449

N

Nais; description and ecology of, 1537
Nassau County; N.Y.; ground water conservation and recharge in, 1495
National Board of Fire Underwriters; municipal fire protection surveys of, 413
Nebraska; *see* Omaha
Neenah, Wis.; main installations at, 284
Negligence; use of drinking water standards in determining utility liability for, 1183
Nematodes; description and ecology of, 1533
examination and identification of, 695
occurrence of, in distribution systems, 603, 613

Newark, Del.; studies of artificial recharge at, 749
New Jersey; *see also* Jersey City
water development program of, 594
New Mexico; *see also* Animas River; Aztec
ground water contamination and recharge in, 1215
New York; *see also* Kingston; Long Island; Nassau County; New York City; Niagara Falls; Queens; Syracuse
artificial-recharge legislation in, 1220
experience with main breaks in, 1045
ground water contamination in, 1217
New York University; fluoridation study by, 305
Niagara Falls; first use of liquid chlorine at, 1416
Nitrate; need for limit on, 297
spectrophotometric determination of, with 2,6-xylenol reagent, 255
Nitrocellulose; steel tank coating with, 1383
Notes and Comment; Delhi, India, hepatitis epidemic, 687
filter sand grain growth due to manganese dioxide, 1580
Standard Methods; history of, 1079
valve installation and maintenance, 1341

O

Oakland County (Mich.) Department of Public Works; organization and operation of, 426
Ohio; *see also* Cleveland
water research activities in, 1116
Ohio River; performance of radial collector wells near, 1206
synthetic-detergent-monitoring program for, 607
US Public Health Service pollution studies on, 1103
Ohio River Valley Water Sanitation Commission; findings of, concerning phenol and taste-and-odor control, 517
membrane filter studies and recommendations of, 229
Oklahoma; *see* Lake Hefner
Omaha, Neb.; growth and regulation of air-conditioning demands at, 278
Ontario Water Resources Commission; organization and research activities of, 1101
Orientation; improvement of mechanical properties of plastics by, 1258
Orsanco; *see* Ohio River Valley Sanitation Commission
Orthophosphate; determination of, 486
Osmionic process; saline-water conversion by, 556, 565
Osmotic-ionic process; saline-water conversion by, 986
Oxidation; manganese removal by, 1330
Oxygen; dissolved; amperometric determination of, 1575

P

Paints; tank; evaluation of, for interiors, 623
dissolution of lead from, 197
types and application of, 191, 1379
Paramecium; description and ecology of, 1525
Pasco, Wash.; removal of radionuclides at, by conventional treatment, 834
Pasteurizer; water; design and operation of, 247
picture of, *February cover*
Pennsylvania; *see* Beaver Falls; Philadelphia; Wilkinsburg
Personnel; customer service, at Philadelphia, 425
maintenance; establishment of work standards for, 699
need for competence in, in water industry, 1171
Personnel relations; manuals as aid in, 711
principles of, 315
promotion and salaries, 1173
role of manager in, 1126
pH; carbonate deposition influenced by, 1388
copper corrosion affected by, 1035
equivalence point; alkalinity determined from, 261
Phenanthroline; determination of ferrous iron with, 1567
Phenol; natural sources of, 518
presence of, in storm water recharge basins, 1498
significance of, in taste and odor control, 505
US Public Health Service recommended limit on, 295
Phenolic paints; performance of, for tank interiors, 627
Phenolic resins; steel tank coating with, 1380
Phenylarsenoxide; dissolved-oxygen determination with, 1575

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 698–814

Philadelphia, Pa.; experience with main breaks at, 1041
handling of customer complaints at, 421
phosphate handling at, 1195
studies of organic compounds in water supply of, 876
Phosphate; concentrations of, in Illinois streams, 471
effects of, on coagulation and sedimentation, 1303
handling of, at Philadelphia, Pa., 1195
total; rapid field determination of, 483
Photography; aerial; use of, in mapping distribution systems, 1129
Pipe; concrete; types and uses of, in water industry, 1244
experience with breaks in, 1041
high-tensile steel for, 1137
metal; carbonate deposits for protection of, 1386
plastic; development and use of, 1251
prestressed concrete; design procedures for, 1397
Pipe joints; failures of, in Indianapolis, Ind., 1055
merits of various types of, 81
Pipelines; concrete; internal repair of, at Cleveland, 437
installation of, across Meramec River, *January cover*, 76
by jacking, 273
with thrust blocks, 81
loss of carrying capacity in, from corrosion and tuberculation, 1263
spacing of valves to combat breaks in, 269
state disinfection practices for, 1425
Plankton; *see also* Aquatic organisms and growths
Lake Hefner, Okla.; effects of hexadecanol on, 796
occurrence of, in South Central United States, 900
Planning; distribution storage; principles of, in nonhilly areas, 714
financial; importance of, to insure adequate water service, 153
role of budgets in, 1125
value of system records in, 277
water resources; federal activities in, 831
water utility construction, 13
Plastic; development and types of, 1251
serviceability of, for meter manufacture, 53
Plastic pipe; British research on, 1095
development of standards for, 1260
Plastic pipe (*contd.*); progress in development of, 1251
suitability of, for water works service, 1259
Plumbing; public health aspects of, 190
Pollution; *see also* Radioactivity; Synthetic detergents
chemical; feasibility of water reuse affected by, 604
coliform organisms as indicators of, 1577
effects of, on water quality, 1349
ground water; causes of, 979
relation of, to underground water disposal, 619
organic-chemical; proposed toxicity-screening procedure for, 689
problem of, 959
radioactive; selection of control measures for, on Animas River, 1287
stream; protection of water resources against, 831
taste and odors caused by, 1363
Polyelectrolytes; *see* Coagulation; Filters
Polyethylene pipe; uses and advantages of, 1253
Polymers; definition of, 1251
Polyphosphate; inadequacy of, as corrosion and scale control, 728
use of, for developing anticorrosion coatings, 721, 1388
Polyvinyl chloride; uses and advantages of pipe made of, 1254
Porifera; description and ecology of, 1527
Potassium permanganate; oxidation of manganese by, 219, 1333
Power; pumping station; reliability of, 717
Pressure acidizing; well stimulation by, 337
Pressure; main breaks caused by, 1042
Protozoa; *see also* Aquatic organisms and growths
resistance of, to treatment, 603
Publications; AWWA; list of, 1607
report on, 520
Public relations; bond issue campaigns, 1015
handling of customer complaints, 421
importance of, in overcoming public apathy, 963
manager's role in, 1125
Midland, Mich., activities in, 460
Pumps; booster; planning for use of, in conjunction with elevated storage, 715
line shaft; economy of, at shallow settings, 1158
submersible; types, costs, and operation of, 1145
Puerto Rico Aqueduct and Sewer Authority; organization and operation of, 6
PVC; *see* Polyvinyl chloride

Q

Quality; drinking-water; state regulation of, 1418
toxicity-screening procedure for, 689
effect of phenols on, 506
evaluation of membrane filters for appraisal of, 229
filter effluent; turbidimetric monitoring of, 1411
impounded-water; effects of vegetation on, 1028
inadequacy of present standards for, 1111
Lake Hefner, Okla.; effects of hexadecanol on, 795
raw-water; state bacteriologic limits on, 1419
revisions of standards of, 1344
US Public Health Service standards of, 1159
value, use, and development of standards for, 1159
Queens, N.Y.; jacking of long pipe section beneath highway at, 273

R

Radioactivity; beta; determination of, 756
contamination of water supplies by, 843
dissolved; relationship of, to rainfall and streamflow, 773
environmental; measurement of, at Monroe, Mich., 1293
natural levels of, in Illinois water resources, 769
health hazard due to, in water, 298
human exposure to, on Animas River, 1271
inclusion of limits on, in US Public Health Service Drinking Water Standards, 1164
increases in, from nuclear-weapons testing, 844
ionizing; types and biologic effects of, 841
National Water Quality Network monitoring of, 756
need for standards to control public health hazards of, 1344
removal of, by treatment and natural processes, 845
significance of, in water supply and treatment, 841
surface water; seasonal variations in, 1297
Radioisotopes; concentrations of, in Animas River, 1273
Radioisotopes (*contd.*); distribution and retention of, in body tissues, 843
environmental concentrations of, at Monroe, Mich., 1301
government regulation and control of, 844
human exposure to, on Animas River, 1276
maximum permissible concentrations of, as criterion of relative importance, 839
removal of, by conventional treatment, 834
significance of, in a water environment, 1279
studies of, in streams, 740, 1352
Radium-226; maximum permissible concentration of, 1273
natural levels of, in Illinois ground water, 772
Rates; allowable return on base of, in Wisconsin, 164
block structures of, 1235
consideration of, in extension of service to new customers, 819
criteria for developing schedules of, 160, 1225
demand; Milwaukee, Wis., schedule of, 1239
desirability of minimums in structures of, 1233
need for realistic schedules of, to pay for improvements, 153
Puerto Rico schedule of, 8
state regulation of, 157
West Virginia regulations and procedures for, 308
Real estate; influence of available water service on, 822
Recalcination; techniques and economics of, for lime recovery, 322
Recharge; *see also* Ground water
artificial; developments in, in various states, 1220
effect of air content of water used for, 1431
Los Angeles, Calif., problems of, 1373
purposes and uses of, 1315
recovery of water from, in well effluents, 1435
studies of, in High Plains of Texas, 1491
at Newark, Del., 749
at Walla Walla, Wash., 1427
in various regions, 1487
use of storm water for, in Nassau County, N.Y., 1496
natural; effects of, in artesian wells, 1440
Recirculation; cleaning of mains by, 1060

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Reclaimed water; ground water recharge with, 1222
probable future use of, to overcome shortages, 968
public health aspects of, for potable supply, 599
Records; accounting; West Virginia requirements for, 308
streamflow; publication of, by US Geological Survey, 737
system; value and use of, in planning, 277
Redevelopment; *see also* Wells; Stimulation
injection well; use of, in recharge operations, 1436
Redox potential; *see* Reduction-oxidation potential
Reduction-oxidation potential; soil corrosiveness indicated by, 642
Referendums; bond issue; winning public support in, 1015
Repair; *see* Maintenance
Reports; maintenance; work measurement by, 701
Reprints; lists of, 198, 372, 465, 659, 802, 833, 964, 1136, 1337, 1385
Research; water supply; list of current projects in, 1113
need for, 1172
progress in, 1085
proposal for AWWA sponsorship of, 1119
US Public Health Service grants for, 1117
Reservoirs; *see also* Storage; Tanks
causes and control of taste and odor in, 1027
concrete; sealing of joints in, 930
number and extent of, in South Central United States, 898
problems of interference organisms in, 904
recreational use; AWWA policy on, 1551
Resins; anion-exchange; studies of fouling of, 875
synthetic; steel tank coating with, 1380
Resistivity; underground corrosion related to, 378
Reuse; *see* Conservation; Reclaimed water
Revenue; estimation of total requirements from, 159
Reverse osmosis; conversion of saline water by, 556, 986
Rheometers; use of, in determinations of well characteristics, 1441
Rhode Island; ground water contamination in, 1217
Richmond, Ind.; occurrence of *Crenothrix polyspora* in filter galleries at, 915
Rosiclare, Ill.; use of fluorspar for fluoridation at, 100
Rotenone; studies of oral toxicity of, to mammals, 1551
Rotifers; description and ecology of, 1530
Roundworms; *see* Nematodes
Rubber; chlorinated; steel tank coating with, 1382
inflatable diversion dam made of, *November cover*, 1373
Runoff; US Geological survey reports on, 737

S

Sacramento, Calif.; demand pattern at, 714
location of distribution storage at, 720
Safety; public health; development of criteria of, 1346
radiologic; formation of standards for, 1343, 1347
Safety programs; organization of, 28
St. Louis, Mo.; taste and odor controls at, 1365
water softening studies at, 106
St. Paul, Minn.; installation and maintenance of gate valves at, 269
Saline-water conversion; Coalinga, Calif., plant for, 585
federal demonstration plants for, 987
federal program for, 983
improved solar still for, 993
review of processes of, 553
Salmonella; ingestion of, by nematodes, 616
Sand; filter; theory of flow in, 941
Scale; *see also* Corrosion
pipe; losses in carrying capacity caused by, 1263
removal of, by metaphosphate, 728
Seattle, Wash.; reservoir site clearing at, *August cover*, 1031
Sea water; *see also* Saline-water conversion
intrusion of; in coastal ground water basins, 1222, 1316, 1496
Sediment; clogging of injection wells by, 1493
interference of, in recharge of unfiltered surface water, 1431
Selenium; colorimetric determination of, 1199
US Public Health Service limit on, 292

Service charges; desirability of, as opposed to minimum charges, 1233
Services; copper; studies of corrosion of, 1037
thawing of, at Marinette, Wis., 287
Sewage; effect of, on stream quality, 1349
public health aspects of reclamation of effluents from, 599
recharge of ground water with treated effluents from, 1222
treatment of, at Pasco, Wash., 837
Shigella; ingestion of, by nematodes, 616
Shooting; well stimulation by, 337
Shortages; *see* Water resources; Development
Shreveport, La.; coagulation basin transfer line improvements at, 461
Silicones; steel tank coating with, 1383
Sludge; alum; formula for formation of, 859
recovery and reuse of, 857
Slurries; handling and feeding of, at Chicago, 847
Snails; description and ecology of, 1546
Sodium aluminate; studies of coagulation with, 852
Sodium hexametaphosphate; manganese stabilization with, 867
Sodium silicofluoride; experiments in handling and feeding of, 848
feedability index for, 303
Softening; *see* Alkalinity; Ion exchange; Lime
Soil; survey of corrosiveness of, 638
underground corrosion related to conductivity of, 378
Solids; suspended; removal of, by induced infiltration, 1317
total; US Public Health Service recommended limit on, 296
Solids-contact process; growth in use of, for pretreatment, 199
recovery of alum sludge by, 862
use of accumulated lime slurry in, 106
Solvent extraction; concentration of organic acids by, 878
conversion of saline water by, 987
removal of sulfate and sulfonates by, 474
South Dakota; organization of AWWA section in, 708
Sow bugs; aquatic; description and ecology of, 1541
Speculation; real estate; protection against, in main extension policies, 819
Speeches; preparation of, 683
Sponges; description and ecology of, 1527
Standard Methods; history of, 1079, 1169
preview of eleventh edition of, 1074
suggested; iodide determination, 919
dissolved-oxygen determination, 1575
ferrous-iron determination, 1567
Standards; AWWA; concrete pipe, scope of, 1249
fabricated steel pipe (C201), 1447
mill-type steel pipe (C202), 1465
positive-displacement meters; revision of, 1133
prestressed concrete cylinder pipe (C301); design requirements of, 1397
construction and maintenance; East Bay Municipal Utility District, Calif., 669
Oakland County, Mich., 430
drinking water; US Public Health Service; legal aspects of, 1181
history of, 1159
practical value of, 1174, 1177
revisions of, 1160, 1161
plastic pipe; development of, 1260
quality; contributions of various groups to, 1417
need for professional development of, 1176
value, use, and development of, 1159
Statistics; ABS contamination, 1355
alum supply and use, 135
British water research investments, 1085
chlorination in Kansas, 888
chlorine supply and use, 125
environmental radioactivity, Monroe, Mich., 1291
filter sand specifications, 951
flow; Ohio River, 763
fluoridation practice, 301, 1513
ground water resources in the High Plains of Texas, 1491
human radiation exposure, on Animas River, 1271
lime recovery costs, at Miami, Fla., 331
phosphate and ABS concentrations in Illinois streams, 471
pipeline failures, 1041
populations receiving water and sewer service, 961
radial collector wells; performance of, in West Virginia, 1208
radioactivity, in Illinois water resources, 769
streamflow; US Geological Survey program for, 735
strontium-90, for US surface waters, 756
water research investments and projects, 1105
water use, in US and European cities, 377

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Statistics (*contd.*); well stimulation, 333, 631, 1499
Steel; high-tensile; uses of, in water industry, 1137
Steel pipe; experience with failures in, in Detroit, Mich., 1049
fabricated; new edition of AWWA standard for, 1447
use of high-tensile plate for, 1138
mill-type; new edition of AWWA standard for, 1447
Steel Structures Painting Council; report of, 623
Steel tanks; paints and resins for, 1379
Stills; solar; experimental designs of, 995
Stimulation; effect of, on well operation costs, 1499
performance of, 333, 631
Storage; chemical; use of multipurpose bins for, 1195
distribution; selection of sites for, in nonhilly areas, 718
influence of, on activity of arsenic-76, 840
multipurpose projects; potential money value of, 832
planning for, in nonhilly areas, 714
Storm water; injection of, for ground water storage in Nassau County, N.Y., 1496
Streamflow; program of data collection on, 735
Strontium-90; maximum permissible concentration of, 1273
surface water concentrations of, in the United States, 756
Styrene; steel tank coating with, 1383
Suburban areas; ABS contamination of well supplies in, 1357
assessment of water service charges to, 1232
financing of extensions to, 815, 1006
problem of fire protection in, 419
Suction wells; *see* Intakes
Sulfate; ferrous; handling and feeding of, at Chicago, 847
US Public Health Service recommended limit on, 295
Sulfuric acid; formation of alum by, in reaction with aluminum hydroxide, 859
Surging; well stimulation by, 336
Synthetic detergents; anionic; contamination of water supplies by, 607, 1218, 1354
oral toxicity studies of, 786
effects of, on coagulation and sedimentation, 1303
ground water contaminated by, 621, 1218
Ohio River monitoring for, 607
Syracuse, N.Y.; saline-water conversion studies at, 570

T

Tampa, Fla; recovery and reuse of alum sludge at, 857
Tanks; chemical storage; protective linings for, 851
elevated; aesthetic improvements in design of, 189
planning for use of, in conjunction with booster pumps, 715
location of, in distribution design, 1067
paints and resins for, 1379
use of high-tensile steel for, 1139
good painting practices for, 191
prestressed concrete; use and construction of, 373
steel; advancements in, 365
tests of paints for interiors of, 623
Tastes and odors; causes and control of, in wooded-area reservoirs, 1027
fish poisons as a factor in, 1563
influence of pollution on, 1363
public health significance of, 1366
removal of, by activated carbon, 910
sources of, in waters of South Central United States, 901
studies of causes and control of, 505
threshold; studies of, for metals, 660
Taxation; Wisconsin publicly owned utilities exempt from, 163
Temperature; ground water; effects of, on performance of artesian wells, 1442
effect of recharge on, 1317
injection water; effect of, on pumped wells, 981
on recharge rates, 1487
waste water; effect of, on streams, 1350
Texas; *see* Dallas; High Plains Underground Water Conservation District
Theis formula; application of, in determining aquifer characteristics, 356
Time study; work measurement by, 700
Tolt River; clearing of reservoir basin on, *August cover*, 1031
Toxaphene; studies of oral toxicity of, to mammals, 1551
Treatment; *see also* Aeration; Chlorination; Coagulation; Filtration; Ion exchange; Lime; Tastes and odors
advances in methods of, 199
high-rate; feasibility and economy of, 1320
methods of, at Pasco, Wash., 837
pasteurizer for, for small supplies, *February cover*, 247
progress in development of index for, 148

Treatment plants; alum supply and use in, 135
chemical handling innovations in, at Philadelphia, Pa., 1195
chlorine supply and use in, 125
design and operation of, at Council Bluffs, Iowa, 852
Tuberculation; pipeline; study of, 1263
Turbidimeters; low-level; for filter effluent monitoring, 1411
submerged-light type of, 215
Turbidity; effects of phosphates on coagulation of, 1303
innovations in removal of, 1319
measurement of, with microphotometer, 206
tests of, as indicators of quality, 1170

U

Unaccounted-for water; control of, 442
Underdrains; filter; porous-plate, 653 (erratum, 878)
Upflow process; recovery of alum sludge by, 862

V

Valves; gate; installation and maintenance of, at St. Paul, 269
influence of piping on operation of, 72
installation and maintenance of, 286, 1341
operating procedures for, in fire emergencies, 1070
role of, in water hammer, 65
Vapor compression; *see* Distillation
Vibratory explosion; well stimulation by, 337
Vinyl coatings; performance of, for tank interiors, 627
steel tank coating with, 1381
Virginia; *see also* Alexandria; Fairfax County Water Authority
likelihood of ground water contamination in, 1216
Viruses; ingestion of, by nematodes, 616
possible waterborne nature of, 1352
Viscosity; effect of, on flow, 946
on recharge rates, 1487

W

Walla Walla, Wash., studies of artificial recharge at, 1427
Washington; *see also* Hanford; Pasco; Seattle; Walla Walla
Washington (*contd.*); artificial-recharge practices in, 1221
cross-connection regulations in, 45
Wastes; *see also* Pollution; Radioactivity
lagooning of, as cause of ground water contamination, 1219
liquid; factors affecting underground movement of, 980
survey of ground water contamination by, in various states, 1211
underground; disposal of, as factor in ground water pollution, 619
Water bugs; *see also* Beetles
long-legged; description and ecology of, 1545
Water facilities; deficiencies in, 1
Water fleas; description and ecology of, 1539
Water hammer; allowances for; in pipeline construction, 84
influence of valve operation on, 65
Water industry; progress of research in, 1085
Water research institute; proposal for AWWA sponsorship of, 1119
Water resources; current studies on, 967
federal development program for, 829
Florida; management of, 970
future shortages in, 966
High Plains of Texas, 1491
New Jersey program for, 594
pollution of, 959
program of data collection on, 735
Water Supply Act (1958); provisions of, 830
Water utility structures; architectural treatment for, 180
Water utilities; grading system for, 1172
long-range planning by, 13
Water Utility Advancement Committee; report of, 541
Water Works Administration Committee; report of, 529
Water Works Practice Committee; report of, 535
Weapons; nuclear; increases in radioactivity from tests of, 844
Wells; application of rotary drilling to, 351
artesian; production analysis of, 1438
effect of recharge on yields of, at Walla Walla, Wash., 1434
injection; clogging of, by sediments in recharge water, 1431, 1493
effects of water temperature and viscosity on, 1487
need for periodic redevelopment of, 1436

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

Wells (*contd.*); radial collector; performance records of, in West Virginia, 1206
use of, to obtain solids-free river water, 1319
survey and analysis of stimulation of, 333, 631, 1499
West Virginia; performance of radial collector wells in, 1206
rate-making regulations and financing in, 308
Wilkinsburg, Pa.; manganese removal at, 220
Winnipeg, Man.; administrative manual as utility management aid at, 709
Wisconsin; *see also* La Crosse; Marinette; Milwaukee; Neenah
earnings of municipally owned utilities in, 162
Work; measurement of, for establishment of standards, 700
Worms; chironomid (bloodworms); description and ecology of, 1542
round; *see* Nematodes
segmented; *see* Annelids

Z

Zeolite process; manganese removal by, 1329
Zeta potential; coagulation affected by, 494
studies of, 503
Zinc; evaluation of methods for determination of, 123
taste threshold concentration of, 665
Zoning regulations; influence of, on design of water utility structures, 184

Jul. 815–958; Aug. 959–1084; Sep. 1085–1224; Oct. 1225–1342; Nov. 1342–1486; Dec. 1487–1640

Author Index

ADAMS, REGINALD B.; manganese removal by oxidation with potassium permanganate, 219

ADELMANN, CHARLES B.; establishment and use of work standards in utility maintenance and construction, 699

ALLEN, E. JERRY; *panel discussion*—control and elimination of cross connections, 44

ALLEN, E. JERRY; taste and odor problems in new reservoirs in wooded areas, 1027

ALLEN, RONALD G.; progress in water supply research—organization and activities of the British Water Research Association, 1085

ANWAR, RASHID A. (*with* BYERRUM & HOPPERT); toxicity of small quantities of cadmium and chromium in drinking water administered to dogs during a 4-year period, 651

ARGO, JOHN W.; design and installation of intakes for Canadian supplies, 88

ARNOLD, GERALD E.; experience with main breaks in four large cities—Philadelphia, 1041

ASAI, RICHARD I. (*with* HARTLEY); suggested method for nitrate determination with 2,6-xylenol reagent, 255

BACK, WILLIAM; electrode for simplified field determination of chloride in ground water, 923

BAFFA, JOHN J. (*chairman*); developments in artificial ground water recharge in the United States, 1220

BAFFA, JOHN J. (*chairman*); purposes of artificial recharge, 1315

BALD, ROBERT E.; standardization of design procedures for prestressed-concrete pipe, 1397

BALLINGER, DWIGHT G. (*with* KRONER & KRAMER); evaluation of laboratory methods for analysis of heavy metals in water, 117

BARRETT, HERBERT F.; study of materials to replace copper-base alloys in meter manufacture—introduction and summary, 53

BARTSCH, ALFRED F. (*with* INGRAM); operators' identification guide to animals associated with potable water supplies, 1521

BAUHAHN, ELMER E. (*with* SCHMID); importance of thrust blocks for pipe installations, 81

BAYLIS, JOHN R.; *discussion*—test program for filter evaluation at Hanford, 214

BAYLIS, JOHN R.; water quality standards—operator's viewpoint, 1169

BAXTER, SAMUEL S.; principles of rate making for publicly owned utilities, 1225

BEAN, ELWOOD L.; water quality standards—need for professional standard, 1176

BERGER, BERNARD B.; public health aspects of water reuse for potable supply, 599

BERRY, ALBERT E.; progress in water supply research—research in Canada, 1099

BERRY, W. J.; *notes and comment*—Delhi hepatitis epidemic, 687

BEVIS, HERBERT A.; significance of radioactivity in water supply and treatment, 341

BIGGS, JOSEPH (*with* KEANE); test of paints for water tank interiors, 623

BLACK, A. P.; basic mechanisms of coagulation, 492

BOLLINGER, CRAMER G. (*with* STAUB); use of aerial photography for preparation of distribution system maps, 1129

BRADT, DAVID M.; review of desalinization processes—distillation processes, 574

BROADHURST, WILLIAM L.; ground water recharge and conservation—practices on the High Plains of Texas, 1491

BYERRUM, RICHARD U.; ANWAR, RASHID A. & HOPPERT, CARL A.; toxicity of small quantities of cadmium and chromium in drinking water administered to dogs during a 4-year period, 651

CARL, KENNETH J.; municipal fire protection surveys as indicators of water system status, 413

CARNS, JAMES G. (*chairman*); progress in revision of the positive-displacement meter standard, 1133

CARY, EDMUND S.; ONGERTH, HENRY J.; & PHELPS, REGINALD O.; domestic water supply demineralization at Coalinga, 585

CHANG, SHIH L.; proposed method for examination of water for free-living nematodes, 695

CHANG, SHIH L.; WOODWARD, RICHARD L.; & KABLER, PAUL W.; survey of free-living nematodes and amebas in municipal supplies, 613

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 698–814

CLARK, DON A. (*with* TSIVOGLOU, SHEARER JR., & JONES); estimating human radiation exposure on the Animas River, 1271
CLARK, EDWARD J.; experience with main breaks in four large cities—New York, 1045
CLARK, HAROLD F. (*with* KABLER); coliform group and fecal coliform organisms as indicators of pollution in drinking water, 1577
CLEASBY, JOHN L.; turbidimetric control of filter effluent quality, 1411
CLOSNER, JOHN J.; use of prestressed concrete for storage facilities, 373
COHEN, JESSE M.; KAMPHAKE, L. J.; HARRIS, E. K. & WOODWARD, RICHARD L.; taste threshold concentrations of metals in drinking water, 660
COHEN, JESSE M.; KAMPHAKE, LAWRENCE J.; LEMKE, ARMOND E.; HENDERSON, CROSWELL; & WOODWARD, RICHARD L.; effect of fish poisons on water supplies—part 1, removal of toxic materials, 1551
COLLINS, CLYDE; installation and maintenance of distribution facilities in Wisconsin—valve and hydrant maintenance at La Crosse, 286
CONLEY, WALTER R. & PITMAN, RAYMOND W.; test program for filter evaluation at Hanford, 205
CONLEY, WALTER R. & PITMAN, RAYMOND W.; innovations in water clarification, 1319
COPLEY, JOHN G.; *joint discussion*—selection of equipment for machine billing operations, 1024
CORBALIS, JAMES J., JR.; organization and problems of the Fairfax County Water Water Authority, 823
COUGHLIN, FRANCIS J. (*with* WEAVER); monitoring the Ohio River for synthetic-detergent content, 607
CRABILL, M. P. (*chairman*); *notes and comment*—questions and answers on biologic infestations, 1081
CROW, WILLIAM B.; techniques and economics of calcining softening sludges—calcination techniques, 322
CULP, RUSSELL L.; history and present status of chlorination practice in Kansas, 888
CYWIN, ALLEN & FINCH, LEWIS S.; federal research and development program for saline-water conversion, 983

DEMPSTER, ANDREW T.; *panel discussion*—control and elimination of cross connections, 41
DERBY, RAY L.; *panel discussion*—control and elimination of cross connections, 42
DERBY, RAY L.; water quality standards—introduction, 1159
DEUEL, ORVILLE P.; earnings of municipally owned utilities in Wisconsin, 162
DE VRIES, THOMAS & SAVARIAR, C. P.; determination of impurities in liquid chlorine, 1338
DIETZ, BERNARD (*with* GOLDMAN); suggested amperometric titration method for determining dissolved oxygen, 1575

EMERY, PAUL M. (*with* HARRISON); architectural treatment for water utility structures, 180
ENGELBRECHT, RICHARD S. (*with* MORGAN); effects of phosphates on coagulation and sedimentation of turbid waters, 1303
ENGELBRECHT, RICHARD S. (*with* MORGAN); survey of phosphate and ABS concentrations in Illinois streams, 471
ERICKSON, CLAUD R.; submersible water well pumps, 1145
ERICKSON, D. L.; *notes and comment*—filter sand grain growth due to manganese dioxide, 1580
ETTINGER, MORRIS B.; *discussion*—evaluating the taste and odor control problem, 514
ETTINGER, M. B.; proposed toxicity screening procedure for use in protecting drinking water quality, 689

FABER, HARRY A.; progress in water supply research—research in the United States, 1102
FASSNACHT, GEORGE G. (*with* SHILLINGER); cross-connection hazards and controls, 36
FEBEN, DOUGLAS; theory of flow in filter media, 940
FEE, JOHN R.; planning distribution storage in nonhilly areas, 714
FINCH, LEWIS S. (*with* CYWIN); federal research and development program for saline-water conversion, 983
FREY, CARL W.; handling customer complaints in the Philadelphia water department, 421
FRISCH, NORMAN W. & KUNIN, ROBERT; organic fouling of anion-exchange resins, 875
FROMAN, CHARLES A.; design and operation of the Midland treatment plant—startup and operation, 455
FUHRMAN, RALPH E.; effects of pollutants in water supplies—sewage and industrial wastes, 1349

GAMET, MERRILL B. & RADEMACHER, JOHN M.; study of short filter runs with Lake Michigan water, 137
GENT, ABEL H.; *discussion*—circulation of water in the Hammond distribution system, 1070
GIDLEY, H. K. & MILLAR, JOHN H.; performance records of radial collector wells in the Ohio River Valley, 1206
GOLDFINGER, HENRY; jacking of long pipe section beneath a highway, 273
GOLDIN, A. S. (*with* STRAUB, SETTER & HALLBACH); strontium-90 in surface water in the United States, 756
GOLDMAN, EUGENE & DIETZ, BERNARD; suggested amperometric titration method determination of dissolved oxygen, 1575
GOLDSTEIN, MELVIN; MCCABE, L. J.; & WOODWARD, RICHARD L.; continuous-flow water pasteurizer for small supplies, 247
GOOCH, ROBERT S.; electronic computers in the water supply field, 311
GRAESER, HENRY J.; main extension policies at Dallas, 1006
GRAYSON, LAUREN W.; water supply—America's greatest challenge, 1
GRIFFIN, ATTMORE E.; significance and removal of manganese in water supplies, 1326
GROOT, CATHARINA R.; feasibility of artificial recharge at Newark, Del., 749
GRUNE, WERNER N. & ZANDI, IRAJ; improved solar still process for desalting sea and brackish waters, 993
GUEST, REX M.; apparatus for corrosion tests with hot municipal waters, 1142
GUILLOU, JOHN C. (*with* LARSON & HENLEY); circulation of water in the Hammond distribution system, 1059
GULLANS, OSCAR (*with* HOPKINS); water quality standards—new USPHS standards, 1161
GULLANS, OSCAR; progress in chemical handling and feeding at Chicago, 847

HALLBACH, PAUL F. (*with* STRAUB, SETTER & GOLDIN); strontium-90 in surface water in the United States, 756
HAMILTON, HUGH L.; effects of soil corrosion on cast-iron pipe, 638
HARRIS, E. K. (*with* COHEN, KAMPHAKE & WOODWARD); taste threshold concentrations of metals in drinking water, 660
HARRISON, RONALD & EMERY, PAUL M.; architectural treatment for water utility structures, 180
HARTLEY, ARNOLD M. & ASAI, RICHARD I.; suggested method for nitrate determination with 2,6-xylenol reagent, 255
HARTUNG, HERBERT O.; effects of pollutants in water supplies—taste and odor, 1363
HARTUNG, HERBERT O. (*with* TUEPKER); effect of accumulated lime-softening slurry on magnesium reduction, 106
HAYWOOD, ROBERT W., JR. (*with* MCCALLUM); 1958 federal Water Supply Act and future water requirements, 829
HELMRICH, WILLIAM; industrial use and conservation at Kingston, 175
HENDERSON, CROSWELL (*with* COHEN, KAMPHAKE, LEMKE & WOODWARD); effect of fish poisons on water supplies—part 1, removal of toxic materials, 1551
HENLEY, LAUREL M. (*with* LARSON & GUILLOU); circulation of water in the Hammond distribution system, 1059
HIRSCH, A. ADLER; improved entry to transfer line in primary sedimentation basin, 461
HOAK, RICHARD D.; *discussion*—evaluating the taste and odor control problem, 517
HOLLIS, MARK D.; pollution and national water resources, 959
HOLZER, ROY W.; installation and maintenance of gate valves in St. Paul, 269
HOPPERT, CARL A. (*with* BYERRUM & ANWAR); toxicity of small quantities of cadmium and chromium in drinking water administered to dogs during a 4-year period, 651
HOPKINS, OMAR C. & GULLANS, OSCAR; water quality standards—new USPHS standards, 1161
HOWSON, LOUIS R.; revenues, rates, and advance planning, 153
HURST, WILLIAM D.; administrative manual of Winnipeg engineering department, 709

ILLIG, GEORGE L., JR.; use of sodium hexametaphosphate in manganese stabilization, 867
IMBERTSON, N. M.; automatic rubber diversion dam in the Los Angeles River, 1373
INGOLS, ROBERT S.; studies on the toxicity and decomposition of fluosilicic acid, 927
INGRAM, WILLIAM M. & BARTSCH, ALFRED F.; operators' identification guide to animals associated with potable water supplies, 1521
IVES, KENNETH J.; simulation of filtration on electronic digital computer, 933

JACKSON, JAMES O.; advancements in steel storage facilities, 365

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

JACKSON, JAMES O.; good practices in painting steel elevated tanks and standpipes, 191
JACKSON, JAMES O.; paints and resins for steel tanks, 1379
JACKSON, JAMES O.; use of high-tensile steels—welded elevated steel tanks and standpipes, 1139
JANSON, VINCENT B.; handling of phosphates at Torresdale treatment plant, 1195
JORDAN, HARRY E.; *discussion*—Puerto Rico Aqueduct and Sewer Authority, 12
JORDAN, HARRY E.; *notes and comment*—history of *Standard Methods*, 1079
JONES, JOHN D. (*with* TSIVOGLOU, SHEARER JR., & CLARK); estimating human radiation exposure on the Animas River, 1271
JUNKINS, ROBERT L.; removal of radionuclides from the Pasco supply by conventional treatment, 834

KABLER, PAUL W. & CLARK, HAROLD F.; coliform group and fecal coliform organisms as indicators of pollution in drinking water, 1577
KABLER, PAUL (*with* CHANG & WOODWARD); survey of free-living nematodes and amebas in municipal supplies, 613
KALINSKE, A. A.; advances in water supply technology, 199
KAMPHAKE, LAWRENCE J. (*with* COHEN, HARRIS & WOODWARD); taste threshold concentrations of metals in drinking water, 660
KAMPHAKE, LAWRENCE J. (*with* COHEN, LEMKE, HENDERSON & WOODWARD); effect of fish poisons on water supplies—part 1, removal of toxic materials, 1551
KEANE, JOHN D. & BIGOS, JOSEPH; test of paints for water tank interiors, 623
KEINATH, HERBERT L.; principles of good employee-management relationships—selection and supervision of employees, 315
KERR, S. LOGAN; effect of valve operation on water hammer, 65
KINCAID, RUSSELL G.; value and use of system records in long-range planning, 277
KINNEY, JOHN E.; evaluating the taste and odor control problem, 505
KIRK, JAMES E.; federal-aid highway policies affecting utilities, 1404
KOENIG, LOUIS; survey and analysis of well stimulation performance, 333
KOENIG, LOUIS; economic aspects of water well stimulation, 631
KOENIG, LOUIS; effects of stimulation on well operating costs and its performance on old and new wells, 1494
KOTHARY, NAVNIT C. (*with* NEHEMIAS & WHIPPLE); environmental radioactivity prior to nuclear power plant operation, 1291
KRAMER, HARRY P. (*with* KRONER & BALLINGER); evaluation of laboratory methods for analysis of heavy metals in water, 117
KRONER, ROBERT C.; BALLINGER, DWIGHT G.; & KRAMER, HARRY P.; evaluation of laboratory methods for analysis of heavy metals in water, 117
KUNIN, ROBERT (*with* FRISCH); organic fouling of anion-exchange resins, 875

LANG, S. M.; interpretation of boundary effects from pumping test data, 356
LARSON, THURSTON E.; loss in pipeline carrying capacity due to corrosion and tuberculation, 1263
LARSON, THURSTON E.; GUILLOU, JOHN C.; & HENLEY, LAUREL M.; circulation of water in the Hammond distribution system, 1059
LARSON, THURSTON E. & WEATHERFORD, RICHARD L.; natural radioactivity in Illinois water resources, 769
LARSON, THURSTON E.; progress in water supply research—proposal for AWWA sponsorship of research, 1119
LAUBUSCH, EDMUND J.; water disinfection practices in the United States, 1416
LEE, G. FRED & STUMM, WERNER; determination of ferrous iron in the presence of ferric iron with bathophenanthroline, 1567
LEMKE, ARMOND E. (*with* COHEN, KAMPHAKE, HENDERSON & WOODWARD); effect of fish poisons on water supplies—part 1, removal of toxic materials, 1551
LEVINE, HARRY (*with* MAGIN, THATCHER & RETTIG); suggested modified method for colorimetric determination of selenium in natural water, 1199
LLOYD, DONALD F.; cost comparison of unmetered and metered systems at Idaho Falls, 433
LOF, GEORGE O. G.; review of desalinization processes—solar distillation, 578
LYNCH, J. J. (*with* THOMAS); determination of carbonate alkalinity in natural waters, 259

MCCABE, L. J., JR. (*with* GOLDSTEIN & WOODWARD); continuous-flow water pasteurizer for small supplies, 247

McCallum, Gordon E. & Haywood, Robert W., Jr.; 1958 federal Water Supply Act and future water requirements, 829
McCauley, Robert F.; controlled desposition of protective calcite coatings in water mains, 1386
McCauley, Robert F.; use of polyphosphates for developing protective calcite coatings, 721
McElhiney, William A.; application of rotary drilling to water wells, 351
McPherson, M. B.; *discussion*—effect of valve operation on water hammer, 72
Magin George B., Jr.; Thatcher, Leland L.; Rettig, Shirley; & Levine, Harry; suggested modified method for colorimetric determination of selenium in natural water, 1199
Maier, F. J.; advances in the use of fluorspar for fluoridation, 97
Maier, F. J. (*chairman*); status of fluoridation in the United States and Canada (1959), 1513
Maloney, Frank E.; water quality standards—legal viewpoint, 1180
Marklund, W. F.; principles of good employee-management relationships—relationships with nonunion employees, 320
Matthews, George E.; principles of good employee-management relationships—winning employee confidence, 317
Millar, John H. (*with* Gidley); performance records of radial collector wells in the Ohio River Valley, 1206
Millar, Robert S.; winning public support for bond issues—Denver, 1018
Miller, Lynn M. (*chairman*); survey of ground water contamination and waste disposal practices, 1211
Miller, Lynn M. (*chairman*); underground waste disposal and ground water contamination, 619
Morgan, James J. & Engelbrecht, Richard S.; effects of phosphates on coagulation and sedimentation of turbid waters, 1303
Morgan, James J. & Engelbrecht, Richard S.; survey of phosphate and ABS concentrations in Illinois streams, 471
Moss, H. V. (*chairman*); ABS and the safety of water supplies, 786
Mumma, Roy M.; internal repairs of concrete conduits at Cleveland, 437

Nehemias, John V.; Whipple, G. Hoyt; & Kothary, Navnit C.; environmental radioactivity prior to nuclear power plant operation, 1291
Nelson, Carl R.; principles of good employee-management relationships—importance of the individual in small utilities, 318
Niemeyer, Howard W.; experience with main breaks in four large cities—Indianapolis, 1051
Noble, Ralph E.; reliability of MPN indexes of coliform organisms, 803
Norman, E. Oliver; water main installation across the Meramec River, 76

Ongerth, Henry J.; *panel discussion*—control and elimination of cross connections, 46
Ongerth, Henry J. (*with* Cary & Phelps); domestic water supply demineralization at Coalinga, 585
Orndorff, Roy L.; leak surveys and control of unaccounted-for water—practices in the District of Columbia, 446

Palmer, C. Mervin; algae and other interference organisms in the waters of the South Central United States, 897
Phelps, Reginald O. (*with* Cary & Ongerth); domestic water supply demineralization at Coalinga, 585
Phillips, Robert S. (*chairman*); status of fluoridation in the United States and Canada (1958), 301
Pitman, Raymond W. (*with* Conley); innovations in water clarification, 1319
Pitman, Raymond W. (*with* Conley); test program for filter evaluation at Hanford, 205
Poss, Robert J.; installation and maintenance of distribution facilities in Wisconsin—thawing of water services at Marinette, 287
Price, H. Arthur; use of high-tensile steels—high-pressure transmission lines, 1137

Rademacher, John M. (*with* Gamet); study of short filter runs with Lake Michigan water, 137
Reichel, Richard C.; study of materials to replace copper-base alloys in meter manufacture—Armour Foundation report, 56
Remus, Gerald J.; changes in judicial concepts of utility liability, 19
Remus, Gerald J.; experience with main breaks in four large cities—Detroit, 1048
Renick, Myron R.; rate-making regulations and financing in West Virginia, 308

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814

RETTIG, SHIRLEY (*with* MAGIN, THATCHER & LEVINE); suggested modified method for colorimetric determination of selenium in natural water, 1199

REW, MYRON E.; use of sodium aluminate as a coagulant at Council Bluffs, 852

RIDDICK, THOMAS M.; *discussion*—basic mechanisms of coagulation, 502

ROBERTS, J. MORAN & RODDY, CHARLES P.; recovery and reuse of alum sludge at Tampa, 857

ROBERTSON, DAVID A., JR. (*with* STREETER); evaluation of membrane filter technique for appraising Ohio River water quality, 229

ROBERTSON, REED S.; rapid method for estimation of total phosphate in water, 483

RODDY, CHARLES P. (*with* ROBERTS); recovery and reuse of alum sludge at Tampa, 857

ROE, FRANK C.; experiences in the use of porous-plate filter bottoms, 653; *erratum*, 874

RORABAUGH, MATTHEW L.; problems of waste disposal and ground water quality, 979

ROSSUM, JOHN R. & VILLARRUZ, PRIMO A.; suggested method for iodide determination, 919

RUSSELL, ROBERT H.; artificial recharge of a well at Walla Walla, 1427

RYNDERS, ARTHUR; demand rates and metering equipment at Milwaukee, 1239

SANDELL, DEWEY J., JR.; review of desalinization processes—freezing processes, 568

SAVARIAR, C. P. (*with* DE VRIES); determination of impurities in liquid chlorine, 1338

SCHAD, THEODORE M.; activities of the Senate Select Committee on National Water Resources, 965

SCHAMBERGER, KARL H.; leak surveys and control of unaccounted-for water—program at Baltimore, 442

SCHMID, GEORGE G. & BAUHAHN, ELMER E.; importance of thrust blocks for pipe installations, 81

SCHONE, HAROLD K.; organization and standards of the Oakland County Department of Public Works, 426

SCHWORM, WILLIAM B.; low-temperature liquid lime slaking at Howard Bend treatment plant, 1189

SCOTT, GORDON N.; distribution of soil conductivity and its relation to underground corrosion, 378

SCOTT, WARREN J. (*chairman*); alum supply and use in water treatment plants, 135

SCOTT, WARREN J. (*chairman*); chlorine supply and use in water and sewage treatment plants, 125

SEEGER, WILLIAM R.; duties and responsibilities of the water utility manager, 1122

SEELEY, JOHN C.; design and operation of the Midland treatment plant—design and construction, 449

SETTER, LLOYD R. (*with* STRAUB, GOLDIN & HALLBACH); strontium-90 in surface water in the United States, 756

SHANKLIN, GEORGE R.; New Jersey state water development program, 594

SHEARER, S. DAVID JR. (*with* TSIVOGLOU, JONES & CLARK); estimating human radiation exposure on the Animas River, 1271

SHILLINGER, WILLIAM D. & FASSNACHT, GEORGE G.; cross-connection hazards and controls, 36

SHULL, KENNETH E. (*chairman*); cold-water corrosion of copper tubing, 1033

SHULL, KENNETH E.; suggested modified aluminon method for aluminum determination, 779

SIEVEKA, ERNEST H.; review of desalinization processes—membrane processes, 556

SILVEY, J. K. G.; physical, chemical, and biologic effects of hexadecanol on Lake Hefner (1958), 791

SIMON, A. L.; production analysis of artesian wells, 1438

SNIEGOCKI, RICHARD T.; ground water recharge and conservation—effects of viscosity and temperature, 1487

SOPP, GEORGE C.; the true price of accidents, 25

SOWDEN, HOWARD J.; winning public support for bond issues—Fergus Falls, 1015

STAUB, WILLIAM S. & BOLLINGER, CRAMER G.; use of aerial photography for preparation of distribution system maps, 1129

STEEL, ERNEST W.; long-range planning by water utilities, 13

STRAUB, CONRAD P.; SETTER, LLOYD R.; GOLDIN, A. S. & HALLBACH, PAUL F.; strontium-90 in surface water in the United States, 756

STREETER, HAROLD W. & ROBERTSON, DAVID A., JR.; evaluation of membrane filter technique for appraising Ohio River water quality, 229

STROBEL, JOSEPH J.; review of desalinization processes—recent developments, 553

STUART, CHARLES L.; economic principles of sound main extension policies, 815
STUMM, WERNER (*with* LEE); determination of ferrous iron in the presence of ferric iron with bathophenanthroline, 1567
SWEITZER, ROBERT J.; developments in plastics and plastic pipe, 1251

TAYLOR, FLOYD B.; cumulative distribution method for evaluating series of fluoride ion test results, 466
THATCHER, LELAND L. (*with* MAGIN, RETTIG & LEVINE); suggested modified method for colorimetric determination of selenium in natural water, 1199
THOMAS, JEROME F. & LYNCH, J. J.; determination of carbonate alkalinity in natural waters, 259
THOMAS, JEROME F. (*with* WELSH); significance of chemical limits in USPHS Drinking Water Standards, 289
TOMPKINS, RICHARD D.; *joint discussion*—selection of equipment for machine billing operations, 1021
TROXLER, PAUL D.; water control progress in the Everglades, 742
TSIVOGLOU, ERNEST C.; SHEARER, S. DAVID JR.; JONES, JOHN D.; CLARK, DON A.; estimating human radiation exposure on the Animas River, 1271
TUEPKER, JONATHAN L. & HARTUNG, HERBERT O.; effect of accumulated lime-softening slurry on magnesium reduction, 106
TUNSTEAD, RICHARD H.; municipalities, contractors, and engineers—a lawyer's viewpoint, 170
TYLER, HENRY WARD; sealing of joints in concrete-paved reservoirs, 930

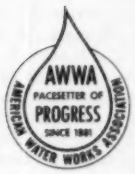
URRUTIA, RAFAEL V.; Puerto Rico Aqueduct and Sewer Authority, 6

VILLAPUZ, PRIMO A. (*with* ROSSUM); suggested method for iodide determination, 919

WAKEFIELD, JOHN W.; water resources and conservation in Florida, 970
WALTON, GRAHAM; effects of pollutants in water supplies—ABS contamination, 1354
WEATHERFORD, RICHARD L. (*with* LARSON); natural radioactivity in Illinois water resources, 769
WEAVER, PAUL J. & COUGHLIN, FRANCIS J.; monitoring the Ohio River for synthetic-detergent content, 607
WELLS, JOSEPH V. B.; changes in the streamflow data collection program of USGS, 735
WELSCH, W. FRED; ground water recharge and conservation—conservation in Nassau County, 1494
WELSH, GENE B. & THOMAS, JEROME F.; significance of chemical limits in USPHS Drinking Water Standards, 289
WERTZ, CLAUDE F.; techniques and economics of calcining softening sludges—Miami lime recovery plant, 326
WESTFAHL, EVERETT; installation and maintenance of distribution facilities in Wisconsin—water main installations at Neenah, 284
WHIPPLE, G. HOYT (*with* NEHEMIAS & KOTHARY); environmental radioactivity prior to nuclear power plant operation, 1291
WHITLOCK, ERNEST W.; concrete pressure pipe in today's water industry, 1244
WOLFE, RALPH S.; microbial concentration of iron and manganese in water with low concentrations of these elements, 1335
WOLMAN, ABEL; concepts of policy in the formulation of so-called standards of health and safety, 1343
WOODWARD, RICHARD L.; significance of pesticides in water supplies, 1367
WOODWARD, RICHARD L. (*with* COHEN, KAMPHAKE, LEMKE & HENDERSON); effect of fish poisons on water supplies—part 1, removal of toxic materials, 1551
WOODWARD, RICHARD L. (*with* GOLDSTEIN & MCCABE); continuous-flow water pasteurizer for small supplies, 247
WOODWARD, RICHARD L. (*with* CHANG & KABLER); survey of free-living nematodes and amebas in municipal supplies, 613
WOODWARD, RICHARD L. (*with* COHEN, KAMPHAKE & HARRIS); taste threshold concentrations of metals in drinking water, 660
WOLFE, RALPH S.; observations and studies of *Crenothrix polyspora*, 915

ZANDI, IRAJ (*with* GRUNE); improved solar still process for desalting sea and brackish waters, 993

Pagination: Jan. 1–152; Feb. 153–288; Mar. 289–412; Apr. 413–552; May 553–688; Jun. 689–814 Jul. 815–958; Aug. 959–1084; Sep. 1085–1224; Oct. 1225–1342; Nov. 1342–1486; Dec. 1487–1640



Journal

AMERICAN WATER WORKS ASSOCIATION

VOLUME 52 • 1960

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Ave., New York 16, N.Y.

Table of Contents

January

Water Supply—America's Greatest Challenge ..... Lauren W. Grayson 1
Puerto Rico Aqueduct and Sewer Authority ..... Rafael V. Urrutia 6
Discussion ..... Harry E. Jordan 12
Long-Range Planning by Water Utilities ..... Ernest W. Steel 13
Changes in Judicial Concepts of Utility Liability ..... Gerald Remus 19
The True Price of Accidents ..... George C. Sopp 25
Cross-Connection Hazards and Controls
William D. Shillinger & George G. Fassnacht 36
New Discount System for AWWA Publications 40
Control and Elimination of Cross Connections—*Panel Discussion*
Andrew T. Dempster, Ray L. Derby, E. Jerry Allen & Henry J. Ongerth 41
Study of Materials to Replace Copper-Base Alloys in Meter Manufacture
Introduction and Summary ..... Herbert F. Barrett 53
Armour Foundation Report ..... Richard C. Reichel 56
Reprints Available 64
Effect of Valve Operation on Water Hammer ..... S. Logan Kerr 65
Discussion ..... M. B. McPherson 72
Water Main Installation Across the Meramec River ..... E. Oliver Norman 76
Importance of Thrust Blocks for Pipe Installations
George G. Schmid & Elmer E. Bauhahn 81
AWWA Meter Manual Available 87
Design and Installation of Intakes for Canadian Supplies ..... John W. Argo 88
Advances in the Use of Fluorspar for Fluoridation ..... F. J. Maier 97
Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction
Jonathan L. Tuepker & Herbert O. Hartung 106
Evaluation of Laboratory Methods for Analysis of Heavy Metals in Water
Robert C. Kroner, Dwight G. Ballinger & Harry P. Kramer 117
Chlorine Supply and Use in Water and Sewage Treatment Plants
Joint Committee Report 125
Alum Supply and Use in Water Treatment Plants ..... Joint Committee Report 135
Study of Short Filter Runs With Lake Michigan Water
Merrill B. Gamet & John M. Rademacher 137
Coagulant Aids for Potable-Water Treatment 152

February

Revenues, Rates, and Advance Planning ..... Louis R. Howson 153
Earnings of Municipally Owned Utilities in Wisconsin ..... Orville P. Deuel 162
Municipalities, Contractors, and Engineers—A Lawyer's Viewpoint
Richard H. Tunstead 170
Industrial Use and Conservation at Kingston ..... William Helmrich 175
Architectural Treatment for Water Utility Structures
Ronald Harrison & Paul M. Emery 180
Plumbing and Public Health 190
Good Practices in Painting Steel Elevated Tanks and Standpipes .. James O. Jackson 191
Reprints Available 198
Advances in Water Supply Technology ..... A. A. Kalinske 199
Test Program for Filter Evaluation at Hanford
Walter R. Conley & Raymond W. Pitman 205
Discussion ..... John R. Baylis 214

Manganese Removal by Oxidation With Potassium Permanganate
REGINALD B. ADAMS 219
Evaluation of Membrane Filter Technique for Appraising Ohio River Water Quality
HAROLD W. STREETER & DAVID A. ROBERTSON JR. 229
Continuous-Flow Water Pasteurizer for Small Supplies
MELVIN GOLDSTEIN, L. J. MCCABE JR. & RICHARD L. WOODWARD 247
Suggested Method for Nitrate Determination With 2,6-Xylenol Reagent
ARNOLD M. HARTLEY & RICHARD I. ASAI 255
Determination of Carbonate Alkalinity in Natural Waters
J. F. J. THOMAS & J. J. LYNCH 259
Installation and Maintenance of Gate Valves in St. Paul....ROY W. HOLZER 269
Jacking of Long Pipe Section Beneath a Highway....HENRY GOLDFINGER 273
Value and Use of System Records in Long-Range Planning....RUSSELL G. KINCAID 277
Installation and Maintenance of Distribution Facilities in Wisconsin
Water Main Installations at Neenah....EVERETT WESTFAHL 284
Valve and Hydrant Maintenance at La Crosse....CLYDE COLLINS 286
Thawing of Water Services at Marinette....ROBERT J. POSS 287

March

Significance of Chemical Limits in USPHS Drinking Water Standards
GENE B. WELSH & JEROME F. THOMAS 289
Status of Fluoridation in the United States and Canada, 1958....TASK GROUP REPORT 301
Rate-Making Regulations and Financing in West Virginia....MYRON R. RENICK 308
Electronic Computers in the Water Supply Field....ROBERT S. GOOCH 311
Principles of Good Employee-Management Relationships
Selection and Supervision of Employees....HERBERT L. KEINATH 315
Winning Employee Confidence....GEORGE E. MATTHEWS 317
Importance of the Individual in Small Utilities....CARL R. NELSON 318
Relationships With Nonunion Employees....W. F. MARKLUND 320
Techniques and Economics of Calcining Softening Sludges
Calcination Techniques....WILLIAM B. CROW 322
Miami Lime Recovery Plant....CLAUDE F. WERTZ 326
Survey and Analysis of Well Stimulation Performance....LOUIS KOENIG 333
Application of Rotary Drilling to Water Wells....WILLIAM A. MCELLHINEY 351
Interpretation of Boundary Effects From Pumping Test Data....S. M. LANG 356
Advancements in Steel Storage Facilities....JAMES O. JACKSON 365
Reprints Available.... 372
Use of Prestressed Concrete for Storage Facilities....JOHN J. CLOSNER 373
Municipal Water Consumption in the United States and Europe.... 377
Distribution of Soil Conductivity and Its Relation to Underground Corrosion
GORDON N. SCOTT 378
Proposed Revision of AWWA Constitution and Bylaws.... 393

April

Municipal Fire Protection Surveys as Indicators of Water System Status
KENNETH J. CARL 413
Handling Customer Complaints in the Philadelphia Water Department..CARL W. FREY 421
Organization and Standards of the Oakland County Department of Public Works
HAROLD K. SCHONE 426
Cost Comparison of Unmetered and Metered Systems at Idaho Falls
DONALD F. LLOYD 433
Internal Repairs of Concrete Conduits at Cleveland....ROY M. MUMMA 437
Coagulant Aids for Potable-Water Treatment.... 441

Leak Surveys and Control of Unaccounted-for Water
Program at Baltimore....Karl H. Schamberger 442
Practices in the District of Columbia....Roy L. Orndorff 446
Design and Operation of the Midland Treatment Plant
Design and Construction....John C. Seeley 449
Startup and Operation....Charles A. Froman 455
Improved Entry to Transfer Line in Primary Sedimentation Basin..A. Adler Hirsch 461
Reprints Available.... 465
Cumulative Distribution Method for Evaluating Series of Fluoride Ion Test Results
Floyd B. Taylor 466
Survey of Phosphate and ABS Concentrations in Illinois Streams
James J. Morgan & Richard S. Engelbrecht 471
Rapid Method for Estimation of Total Phosphate in Water....Reed S. Robertson 483
Basic Mechanisms of Coagulation....A. P. Black 492
Discussion....Thomas M. Riddick 502
Evaluating the Taste and Odor Control Problem....John E. Kinney 505
Discussion....Morris B. Ettinger 514
Discussion....Richard D. Hoak 517
Report on Publications.... 520
Report of the Committee on Water Works Administration.... 529
Report of the Committee on Water Works Practice.... 535
Report of the Committee on Water Utility Advancement.... 541
Report of the Audit of Association Funds.... 545
Section Membership Awards and Statistics.... 551

May

Review of Desalinization Processes
Recent Developments....Joseph J. Strobel 553
Membrane Processes....Ernest H. Sieveka 556
Freezing Processes....Dewey J. Sandell Jr. 568
Distillation Processes....David M. Bradt 574
Solar Distillation....George O. G. Lof 578
Domestic Water Supply Demineralization at Coalinga
Edmund S. Cary, Henry J. Ongerth & Reginald O. Phelps 585
New Jersey State Water Development Program....George R. Shanklin 594
Public Health Aspects of Water Reuse for Potable Supply....Bernard B. Berger 599
Monitoring the Ohio River for Synthetic-Detergent Content
Paul J. Weaver & Francis J. Coughlin 607
Survey of Free-Living Nematodes and Amebas in Municipal Supplies
Shih L. Chang, Richard L. Woodward & Paul W. Kabler 613
Underground Waste Disposal and Ground Water Contamination..Task Group Report 619
Test of Paints for Water Tank Interiors....John D. Keane & Joseph Bigos 623
Economic Aspects of Water Well Stimulation....Louis Koenig 631
Effects of Soil Corrosion on Cast-Iron Pipe....Hugh L. Hamilton 638
Toxicity of Small Quantities of Cadmium and Chromium in Drinking Water Administered to Dogs During a 4-Year Period
Richard U. Byerrum, Rashid A. Anwar & Carl A. Hoppert 651
Experiences in the Use of Porous-Plate Filter Bottoms....Frank C. Roe 653
Reprints Available.... 659
Taste Threshold Concentrations of Metals in Drinking Water
Jesse M. Cohen, L. J. Kamphake, E. K. Harris & Richard L. Woodward 660
Style Manual for Journal Authors....Editorial Statement 671
Notes and Comment: Delhi Hepatitis Epidemic....W. J. Berry 687

June

Proposed Toxicity Screening Procedure for Use in Protecting Drinking-Water Quality ..... M. B. ETTINGER 689
Proposed Method for Examination of Water for Free-Living Nematodes SHIH L. CHANG 695
Establishment and Use of Work Standards in Utility Maintenance and Construction CHARLES B. ADELMANN 699
Connecticut and South Dakota Sections Organized 708
Administrative Manual of Winnipeg Engineering Department .... WILLIAM D. HURST 709
Planning Distribution Storage in Nonhilly Areas ..... JOHN R. FEE 714
Use of Polyphosphates for Developing Protective Calcite Coatings ROBERT F. MCCAULEY 721
Changes in the Streamflow Data Collection Program of USGS JOSEPH V. B. WELLS 735
Water Control Progress in the Everglades ..... PAUL D. TROXLER 742
Feasibility of Artificial Recharge at Newark, Del. ..... CATHARINA R. GROOT 749
Strontium-90 in Surface Water in the United States CONRAD P. STRAUB, LLOYD R. SETTER, A. S. GOLDIN & PAUL F. HALLBACH 756
Natural Radioactivity in Illinois Water Resources THURSTON E. LARSON & RICHARD L. WEATHERFORD 769
Sugested Modified Aluminon Method for Aluminum Determination KENNETH E. SHULL 779
ABS and the Safety of Water Supplies ..... AASGP COMMITTEE REPORT 786
Physical, Chemical, and Biologic Effects of Hexadecanol on Lake Hefner, 1958 J. K. G. SILVEY 791
Reprints Available 802
Reliability of MPN Indexes of Coliform Organisms ..... RALPH E. NOBLE 803

July

Economic Principles of Sound Main Extension Policies ..... CHARLES L. STUART 815
Organization and Problems of the Fairfax County Water Authority JAMES J. CORBALIS JR. 823
1958 Federal Water Supply Act and Future Water Requirements GORDON E. MCCALLUM & ROBERT W. HAYWOOD JR. 829
Reprints Available 833
Removal of Radionuclides From the Pasco Supply by Conventional Treatment ROBERT L. JUNKINS 834
Significance of Radioactivity in Water Supply and Treatment .... HERBERT A. BEVIS 841
Progress in Chemical Handling and Feeding at Chicago ..... OSCAR GULLANS 847
Use of Sodium Aluminate as a Coagulant at Council Bluffs ..... MYRON E. REW 852
Recovery and Reuse of Alum Sludge at Tampa J. MORAN ROBERTS & CHARLES P. RODDY 857
Use of Sodium Hexametaphosphate in Manganese Stabilization .. GEORGE L. ILLIG JR. 867
Correction—Use of Porous-Plate Filter Bottoms (FRANK C. ROE) 874
Organic Fouling of Anion-Exchange Resins .. NORMAN W. FRISCH & ROBERT KUNIN 875
History and Present Status of Chlorination Practice in Kansas .... RUSSELL L. CULP 888
Algae and Other Interference Organisms in the Waters of the South Central United States ..... C. MERVIN PALMER 897
Observations and Studies of *Crenothrix polyspora* ..... RALPH S. WOLFE 915
Suggested Method for Iodide Determination .. JOHN R. ROSSUM & PRIMO A. VILLARRUZ 919
Electrode for Simplified Field Determination of Chloride in Ground Water WILLIAM BACK 923
Studies on the Toxicity and Decomposition of Fluosilicic Acid .... ROBERT S. INGOLS 927

Sealing of Joints in Concrete-Paved Reservoirs....Henry Ward Tyler 930
Stimulation of Filtration on Electronic Digital Computer....Kenneth J. Ives 933
Theory of Flow in Filter Media....Douglas Feben 940

August

Pollution and National Water Resources....Mark D. Hollis 959
Reprints Available.... 964
Activities of the Senate Select Committee on National Water Resources
Theodore M. Schad 965
Coagulant Aids for Potable-Water Treatment.... 969
Water Resources and Conservation in Florida....John W. Wakefield 970
Problems of Waste Disposal and Ground Water Quality..Matthew L. Rorabaugh 979
Federal Research and Development Program for Saline-Water Conversion
Allen Cywin & Lewis S. Finch 983
Improved Solar Still Process for Desalting Sea and Brackish Waters
Werner N. Grune & Iraj Zandi 993
Main Extension Policies at Dallas....Henry J. Graeser 1006
Winning Public Support for Bond Issues
Fergus Falls....Howard J. Sowden 1015
Denver....Robert S. Millar 1018
Selection of Equipment for Machine Billing Operations—*Joint Discussion*
Richard D. Tompkins & John G. Copley 1021
Taste and Odor Problems in New Reservoirs in Wooded Areas....E. Jerry Allen 1027
Cold-Water Corrosion of Copper Tubing....Task Group Report 1033
Experience With Main Breaks in Four Large Cities
Philadelphia....Gerald E. Arnold 1041
New York....Edward J. Clark 1045
Detroit....Gerald J. Remus 1048
Indianapolis....Howard W. Niemeyer 1051
Circulation of Water in the Hammond Distribution System
Thurston E. Larson, John C. Guillou & Laurel M. Henley 1059
Discussion....Abel H. Gent 1070
Annual Report of Joint Committee on Uniformity of Methods of Water Examination 1072
Preview of the Eleventh Edition of *Standard Methods*.... 1074
Notes and Comment:
History of *Standard Methods*....Harry E. Jordan 1079
Questions and Answers on Biologic Infestations....Task Group 2670 P 1081

September

Progress in Water Supply Research
Organization and Activities of the British Water Research Association
Ronald G. Allen 1085
Research in Canada....Albert E. Berry 1099
Research in the United States....Harry A. Faber 1102
Proposal for AWWA Sponsorship of Research....Thurston E. Larson 1119
Duties and Responsibilities of the Water Utility Manager....William R. Seeger 1122
Use of Aerial Photography for Preparation of Distribution System Maps
William S. Staub & Cramer G. Bollinger 1129
Progress in Revision of the Positive-Displacement Meter Standard
Committee Report 1133
Reprints Available.... 1136
Use of High-Tensile Steels
High-Pressure Transmission Lines....H. Arthur Price 1137
Welded Elevated Steel Tanks and Standpipes....James O. Jackson 1139

Apparatus for Corrosion Tests With Hot Municipal Waters.....Rex M. Guest 1142
Submersible Water Well Pumps.....Claude R. Erickson 1145
Water Quality Standards
Introduction.....Ray L. Derby 1159
New USPHS Standards.....Omar C. Hopkins & Oscar Gullans 1161
Operator's Viewpoint.....John R. Baylis 1169
Need for Professional Standard.....Elwood L. Bean 1176
Legal Viewpoint.....Frank E. Maloney 1180
Low-Temperature Liquid Lime Slaking at Howard Bend Treatment Plant
William B. Schworm 1189
Handling of Phosphates at Torresdale Treatment Plant.....Vincent B. Janson 1195
Suggested Modified Method for Colorimetric Determination of Selenium in Natural Water.....George B. Magin Jr., Leland L. Thatcher, Shirley Rettig & Harry Levine 1199
Performance Records of Radial Collector Wells in the Ohio River Valley
H. K. Gidley & John H. Millar 1206
Survey of Ground Water Contamination and Waste Disposal Practices
Task Group Report 1211
Developments in Artificial Ground Water Recharge in the United States
Task Group Report 1220

October

Principles of Rate Making for Publicly Owned Utilities.....Samuel S. Baxter 1225
Demand Rates and Metering Equipment at Milwaukee.....Arthur Rynders 1239
Concrete Pressure Pipe in Today's Water Industry.....Ernest W. Whitlock 1244
Developments in Plastics and Plastic Pipe.....Robert J. Sweitzer 1251
Loss in Pipeline Carrying Capacity Due to Corrosion and Tuberculation
Thurston E. Larson 1263
Estimating Human Radiation Exposure on the Animas River
Ernest C. Tsivoglou, S. David Shearer, Jr., John D. Jones & Don A. Clark 1271
Environmental Radioactivity Prior to Nuclear Power Plant Operation
John V. Nehemias, G. Hoyt Whipple & Navnit C. Kothary 1291
Effects of Phosphates on Coagulation and Sedimentation of Turbid Waters
James J. Morgan & Richard S. Engelbrecht 1303
Purposes of Artificial Recharge.....Task Group Report 1315
Innovations in Water Clarification.....Walter R. Conley & Raymond W. Pitman 1319
Significance and Removal of Manganese in Water Supplies.....Attmore E. Griffin 1326
Microbial Concentration of Iron and Manganese in Water With Low Concentrations of These Elements.....Ralph S. Wolfe 1335
Reprints Available..... 1337
Determination of Impurities in Liquid Chlorine..Thomas De Vries & C. P. Savariar 1338
Notes and Comment: Valve Installation and Maintenance.....F. S. Wicks 1341

November

Concepts of Policy in the Formulation of So-Called Standards of Health and Safety
Abel Wolman 1343
Effects of Pollutants in Water Supplies
Sewage and Industrial Wastes.....Ralph E. Fuhrman 1349
ABS Contamination.....Graham Walton 1354
Taste and Odor.....Herbert O. Hartung 1363
Significance of Pesticides in Water Supplies.....Richard L. Woodward 1367
Automatic Rubber Diversion Dam in the Los Angeles River.....N. M. Imbertson 1373
Paints and Resins for Steel Tanks.....James O. Jackson 1379

Reprints Available 1385
Controlled Deposition of Protective Calcite Coatings in Water Mains
ROBERT F. MCCAULEY 1386
Standardization of Design Procedures for Prestressed-Concrete Pipe..ROBERT E. BALD 1397
Federal-Aid Highway Policies Affecting Utilities.....JAMES E. KIRK 1404
Turbidimetric Control of Filter Effluent Quality.....JOHN L. CLEASBY 1411
Coagulant Aids in Potable-Water Treatment..... 1415
Water Disinfection Practices in the United States.....EDMUND J. LAUBUSCH 1416
Artificial Recharge of a Well at Walla Walla.....ROBERT H. RUSSELL 1427
Production Analysis of Artesian Wells.....A. L. SIMON 1438
Tentative AWWA Standard for Fabricated Electrically Welded Steel Water Pipe
AWWA C201-60T 1447
Tentative AWWA Standard for Mill-Type Steel Water Pipe....AWWA C202-60T 1465

December

Ground Water Recharge and Conservation
Effects of Viscosity and Temperature.....RICHARD T. SNIEGOCKI 1487
Practices on the High Plains of Texas.....WILLIAM L. BROADHURST 1491
Conservation in Nassau County.....W. FRED WELSCH 1494
Effects of Stimulation on Well Operating Costs and Its Performance on Old and New Wells.....LOUIS KOENIG 1499
Status of Fluoridation in the United States and Canada, 1959....TASK GROUP REPORT 1513
Operators' Identification Guide to Animals Associated With Potable Water Supplies
WILLIAM M. INGRAM & ALFRED F. BARTSCH 1521
Effect of Fish Poisons on Water Supplies—Part 1: Removal of Toxic Materials
JESSE M. COHEN, LAWRENCE J. KAMPHAKE, ARMOND E. LEMKE, CROSWELL HENDERSON & RICHARD L. WOODWARD 1551
Binding the Year's Journals..... 1566
Determination of Ferrous Iron in the Presence of Ferric Iron With Bathophenanthroline.....G. FRED LEE & WERNER STUMM 1567
Suggested Amperometric Titration Method for Determining Dissolved Oxygen
EUGENE GOLDMAN & BERNARD DIETZ 1575
Coliform Group and Fecal Coliform Organisms as Indicators of Pollution in Drinking Water.....PAUL W. KABLER & HAROLD F. CLARK 1577
Notes and Comment: Filter and Sand Growth Due to Manganese Dioxide
D. L. ERICKSON 1580
80th Annual Conference—Bal Harbour..... 1581
Papers Scheduled at 1960 Section Meetings..... 1593
AWWA Publications List..... 1607
Index for Volume 52, 1960
Subject Index..... 1615
Author Index..... 1634

© *1960 by the American Water Works Association, Inc.*

"Best salesman
our town ever had!"

AQUA NUCHAR
ACTIVATED CARBON
for taste and odor control

"It's a fact, Joe!

"Every person stopping in our town, even for only a few hours, samples our water...and gets a chance to judge us.

"The clear, fresh-tasting water we serve makes a good impression. It's the best salesman our town ever had."

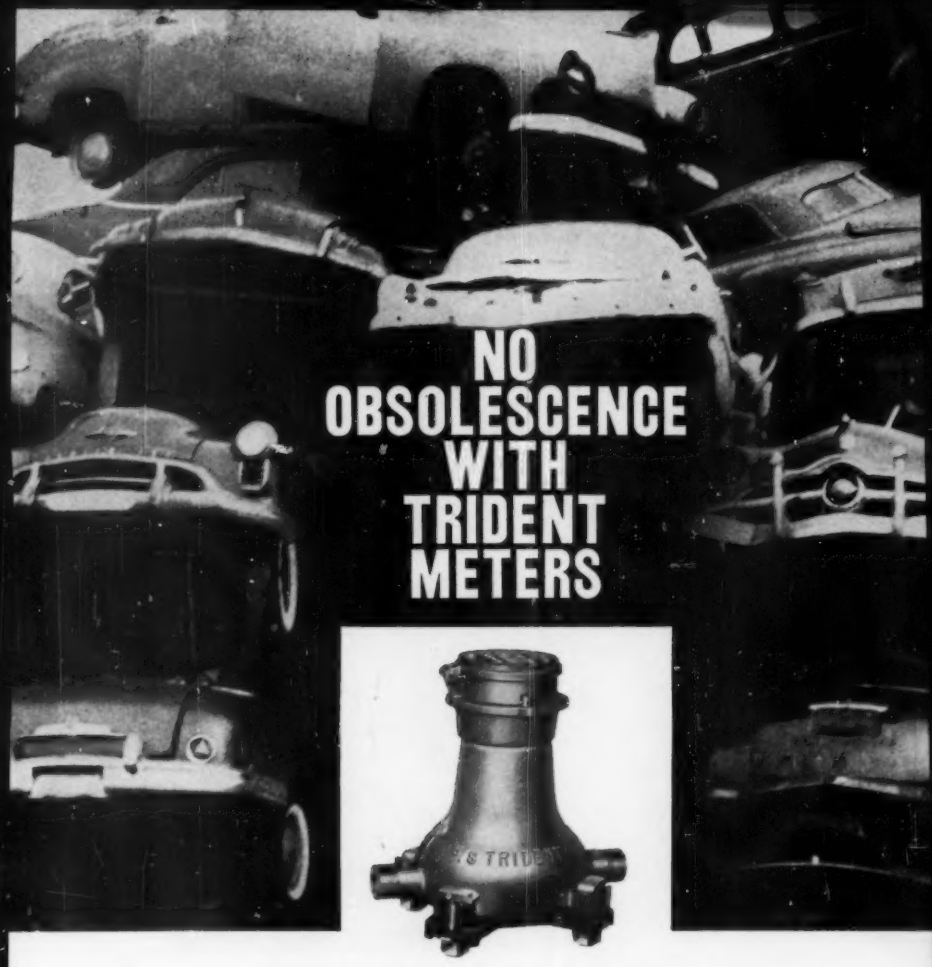
What about the water supply in *your* town? Does it impress visitors favorably? Do townspeople compare it unfavorably with water they drink elsewhere?

If you aren't sure your water is *consistently palatable*, let AQUA NUCHAR's field representative survey your plant and recommend sound taste-and-odor-control procedures. Simple daily threshold odor tests and the accurately measured use of AQUA NUCHAR controls taste-and-odor at a cost of only a few cents a day.

Why not write or phone us today?

West Virginia Pulp and Paper
INDUSTRIAL CHEMICAL SALES DIVISION

230 Park Ave., New York 17 · Philadelphia National Bank Bldg., Philadelphia 7
35 E. Wacker Dr., Chicago 1 · 2775 S. Moreland Blvd., Cleveland 20



NO OBSOLESCENCE WITH TRIDENT METERS

Being modern is the continuous process of going out-of-date tomorrow. Look at the record of Trident design improvements and you'll find this statement is just as true of water meters as it is of automobiles . . . *with one exception.* ■ With Trident meters, your department is probably the only service in your community equipped with *built-in modernization* . . . a process which eliminates the high cost of obsolescence. ■ Here's how it works. ■ Every time you replace work-worn parts in a Trident disc meter, you automatically use *modern* parts identical to those in the *latest* model . . . parts embodying every thoroughly tested advancement known to the science of metering. ■ *All of the many design improvements now on our drawing boards continue this long standing Neptune policy.*

neptune
TRIDENT WATER METERS

NEPTUNE METER COMPANY ■ LIQUID METER DIVISION

47-25 34th St., Long Island City 1, N. Y./Neptune Meters, Ltd., 1430 Lakeshore Rd., Toronto 14, Ont.
Offices in Principal Cities

Merry Christmas

Soaring in the 60's is the list of Editors Anonymous today, when only 13 years ago P&R was almost absolutely listless. Behind the burgeoning, no doubt, has been some measure of unwitting enlistment, for which we are no less wittingly grateful, but what really sends us into panegyrics is the number and industry of P&R's intentional contributors. On the list below, these will be somewhat suggested by their superior powers. Certainly the nine who are marked as at least decadent succors can be assumed to do us good deliberately.

For those who are uninitiated in P&Rgot, we hasten to explain that the basic material from which most of the Percolation and Runoff section is derived is contributed by members in the form of newspaper clippings or other source items. In an effort to arrogate to ourself full credit for the material, we render both it and its contributors unrecognizable—it being linguicized and they being made members of Editors Anonymous. But once a year, at Christmas time, our conscience catches up with us (before any congressional committee can) and we force ourself to admit not only that we did have help, but who provided it and, by the powers, for how many years he has been doing so.

In wishing our '60 66 Merry Christmas, we have especially commended to Santa the nine EA's who have been with us for 10 years or more: Ellsworth Filby, Harry Jordan, Joe Wafer, and Syd Wilson who haven't missed a year since P&R was first perpetrated; and Charlie Capen, Dan Fischel, Wendell LaDue, Sig Sigworth, and Doc Symons who haven't missed more than thrice. And if what we grind with their grist is not particularly to your taste, remember the season and join us in wishing a Merry Christmas to our

EDITORS ANONYMOUS

G. E. Arnold[8]
H. W. Badley[4]
E. A. Bell[2]
D. D. Berhow[4]
A. P. Black[7]
A. P. Brigham[2]
C. H. Capen[10]
E. J. Cleary[8]
E. T. Cloonan[2]
E. S. Cole[1]
D. C. Colebaugh[6]
R. L. Culp[8]
N. M. deJarnette[6]
D. E. Dimmers[2]
J. M. Diven[6]
J. E. Drudy[4]
G. H Dyer[3]
G. R. Evans[2]
Chet Eyer[1]
H. A. Faber[5]
E. L. Filby[10]
D. N. Fischel[12]
M. E. Flentje[9]
J. L. Ford[2]
R. V. Ford[4]
W. S. Foster[3]
J. L. Geren[1]
James Girand[4]
Philip Grannan[6]
B. S. Grant[3]
A. E. Griffin[5]
P. D. Haney[3]
R. E. Hansen[6]
M. J. Harper[6]
W. D. Hurst[1]
R. L. Johnson[8]
H. E. Jordan[10]
J. E. Kleinhenz[7]
Louis Koenig[1]
W. R. LaDue[10]
T. E. Larson[3]
R. E. Lawrence[1]

(*Continued on page 32 P&R*)

(Continued from page 31 P&R)

Fred Merryfield[5] W. B. Schworm[8]
Mildred Merryfield[4] G. R. Scott[8]
R. S. Millar[8] E. A. Sigworth[12]
C. E. Painter[8] G. E. Symons[11]
Steve Painter[1] J. M. Wafer[10]
B. E. Payne[6] Henry Wilkens[8]
G. E. Rickard[1] D. B. Williams[9]
J. S. Rosapepe[6] P. S. Wilson[10]
Helen Rotthaus[1] W. R. Wise[1]
J. M. Sanchis[3] Abel Wolman[1]
M. D. Saunders[4] C. V. Wright[1]
J. C. Zufelt[2]

And especially from them to us, we wish ourself a Happy New Year.

No place like space seems to be the sales pitch these days on the defense—and therefore on the national interest—front. We must get a man into space, we are told, before the Soviets do—regardless of how fantastic the expense may be. And it is not for us to ask if the money would not be wiser spent in putting all the Soviets into space at the earliest possible moment, thereby, perhaps, to permit us to enjoy life down here again. Enjoying life is not quite the idea; the idea is survival. And our learning quickly how to live in space seems to be a struggle for survival, not in terms of outmaneuvering our enemies in interstellar combat, but in finding, through this means, "a place to hide" when the H-bombs begin to make the earth uninhabitable.

All this effort, we recognize, is a great catalyst to scientific endeavor and discovery. Crash effort in space exploration is certain to open new vistas of knowledge about our universe and, thus, presumably, make us better able to cope with it. But we get a distinct impression that we know more now than we have learned to cope with. And it would seem almost more sensible to invest in a crash effort toward preventing war instead of just preventing our extinction by it.

As a matter of fact, we rather wonder if we wouldn't prefer being extinct to being just "preserved," breathing our own exhalations, eating algae which feed directly on our body wastes, and drinking our own deconstituted urine. Of course, our present life cycle isn't fundamentally different from that, but it is those fundamentals that we'd rather not get down to. If we must, though, we must. And we certainly must if we are spacebound, for our minimum annual needs for oxygen, food, and water—600 lb, 400 lb, and 2,000 lb—far outweigh our ability to carry them with us.

Breathing, it appears, can be provided for without too great difficulty, first, by the use of potassium superoxide, which releases oxygen when activated by exhaled carbon dioxide and water vapor in a man's breath, and, second, by the oxygen produced in the algae farms aboard (space) ship.

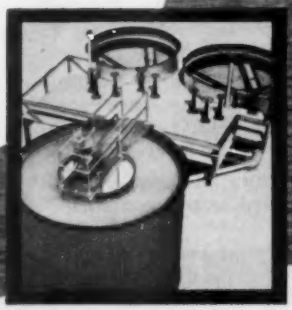
The basic production of the algae farms, fed directly by our body wastes, would, of course, be food. Algae, we learn, can be treated so they taste like many different foods, including steak, fish, coffee, and tea, and they do provide the bulk that is not taken care of by concentrated capsule foods. Then, too, it is possible to feed the algae to such animals as the crustacean, *Daphnia* (the water flea), which, mixed with algae, is reported to be palatable as a soup, either cooked or uncooked. We understand, too, that the soup can be dehydrated into a paste or into dried cakes with a taste somewhat similar to shrimp, but which can be flavored to taste like eggs or, again, steak. "Water flea steak" is what *Science*

(Continued on page 34 P&R)

You can have...

15 to 350 gpm high quality water at low cost!

...with the ACCELAPAK® Treating Plant



Are you looking for a clarification or softening plant which can be installed at comparatively low cost and will produce high-quality water with very little supervision? The "ACCELAPAK" treating plant is your answer. It is specifically designed for small communities, construction camps, sub-divisions, industrial plants, resorts and estates.

This dependable, efficient package type plant includes an ACCELATOR® clarifier or softener, lime slurry, coagulant, and hypochlorite feeders, raw water controller, and gravity or pressure filters.

It can easily be incorporated in engineering for new plants or adapted to existing structures.

INFILCO KNOWS HOW... to help you solve your problem. Over 3,000 "ACCELATOR" units are now in successful operation. If you are tolerating inferior water or makeshift methods of treatment, investigate the "ACCELAPAK" plant. Write today for Bulletin 1870-B.

INFILCO Incorporated

General Offices—Tucson, Arizona

The **one** company offering equipment for all types of water and waste treatment

Field Offices throughout the United States and in other countries.

435-60

(*Continued from page 32 P&R*)

News Letter called it. And as Dr. John R. Olive of Colorado State University pointed out: "Although the algae and water fleas have not been set up in a closed system which uses human waste products, studies show that the water fleas get along pretty well on solid wastes from mice, or brewers yeast, and on horse urine."

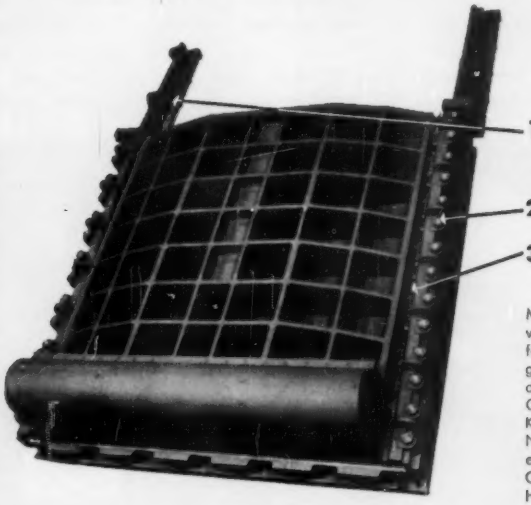
As far as drinking is concerned (and we are supposed to be selling the idea of a *quality* water), there seems to be no essential problem in deconstituting urine. In the 7-day space capsule test conducted last spring at Wright Field in Dayton, Ohio, the encapsulated subject, Courtney Metzger, described the urine-derived water as tasting "better than ordinary water that had been stored aboard for a week." And Col. John Stapp, in charge of the experiment for the Air Force, indicated that, to him, it did not "taste any worse than some of the things you get at cocktail parties."

There has been no discussion yet on the provisions for carrying along micro-microfilm of our books and paintings and other art and architecture, of tapes of our music and our speeches. And we assume that the golf courses and ski slopes will be strictly psychogenic. But we hope that, if we *must* give up fresh air, good food and drink, and the finer things, there will be four aboard for bridge.

Abel Wolman (right), former AWWA President and Journal editor, was honored by APHA on Oct. 20, when he received one of seven Albert Lasker Awards presented for 1960. His award was for "contributions to public health and safety in sanitary engineering, water supply development, and control of radiation hazards." Also above is Mrs. Albert Lasker, making the presentation, and Dr. Francis Crick of Cambridge University, England, another awardee.

(*Continued on page 36 P&R*)

2,300 pounds of Everdur used in new 8-ton cast-iron sluice gate



1 ¾" x 3" Everdur facing strips for gate leaf and frame.

2 1½" Everdur bolts and nuts.

3 Everdur adjusting bolts for cast-bronze wedges.

More than a ton of Everdur was used for facing strips and fastenings in this 8' x 8' sluice gate leaf and frame assembly designed and furnished by the Coldwell-Wilcox Division of Krajewski-Pesant Mfg. Corp., New York City. Consulting engineers, Gannett Fleming Corddry & Carpenter, Inc., Harrisburg, Pa.

This direct-pressure type sluice gate is one of two recently installed by Empresa de Energia Electrica at the Quebradona Dam in Columbia, South America, to regulate the flow of potable water to the city of Medellin.

The 100-foot head of water behind the dam exerts 450,000 pounds pressure on each 8 x 8-foot gate. Everdur* (copper-silicon alloy) was selected to seal against this load because of its high strength and corrosion resistance—plus ready workability and weldability. Sewage treatment and waterworks equipment of Everdur has been in service without replacement for a quarter century and longer.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont. 57133L

*Reg. U.S. Pat. Off. 57133

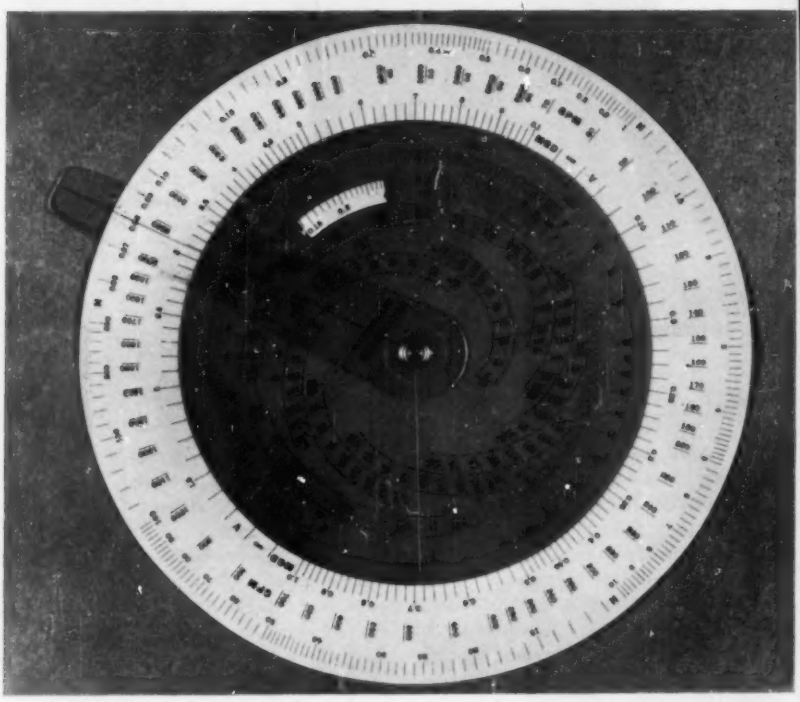
EVERDUR Anaconda's Family of Copper-Silicon Alloys

ANACONDA AMERICAN BRASS COMPANY

STRONG • WORKABLE • WELDABLE • CORROSION-RESISTANT

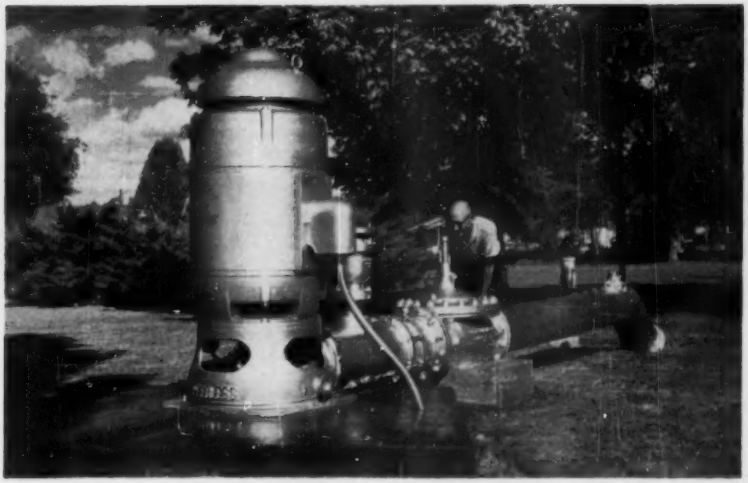
(Continued from page 34 P&R)

High C can be calculated, if not reached, with a new instrument available to the field—a circular hydraulic calculator (see cut) developed, produced, and distributed by Robert E. Martin, Louisville, Ky., consulting engineer. Beautifully made and incorporating a number of new ideas, the calculator has been found to be both accurate and easy to use. A limitation is that it does not permit precision in reporting *C* values between the even 10's. For most calculations, however, where great precision is not required, the calculator provides a useful new tool at no great expense ($6). Further information is available through inventor Martin at 5402 Preston Highway, Louisville 13, Ky.



Public Works Men of the Year include four AWWA members among ten selected as part of the National Public Works Week celebration last Oct. 2–8. Honored as being one of the ten most outstanding men in the public works field by a panel of judges chosen by the American Public Works Assn. and Kiwanis International were these AWWA members: Samuel S. Baxter, commissioner and chief engineer of the Philadelphia Water Dept., who is now a Pennsylvania Section director and who will become a mem-

(Continued on page 38 P&R)



"The service is rough, but we've never experienced a pump failure since the first Peerless pump was installed in 1932."

Says Farrell McLean, Water Superintendent Carlsbad, New Mexico

This is one of the ten Peerless Deepwell Turbine Pumps used to supply the entire city water supply. Pump setting is 80' with 1800 GPM flow.

First installed in 1932, this Peerless pump is still on the job. Like the other nine pumps, this unit is handling water with 50 grains total hardness per gal.

Pumping water with 50 grains of Total Hardness per gallon is rough service in anybody's language. Yet that is exactly what Peerless Deepwell Turbines have been doing, better than 28 years for the city of Carlsbad, New Mexico. The first installation was made in 1932. And, through the years, nine more units have been added to the field to meet the city's increasing water needs. The pumps are operated on continuous duty for periods ranging from four to six months and semi-continuous duty the balance of the year. To date they have never had a pump failure and even the regular maintenance programs call for pulling pumps only every six to seven years for inspection. For the complete story on Peerless Deepwell Pumps, write us.

PEERLESS PUMP

HYDRODYNAMICS DIVISION

FOOD MACHINERY AND CHEMICAL CORPORATION

301 WEST AVENUE 26, LOS ANGELES 31, CALIFORNIA

(*Continued from page 36 P&R*)

ber of the Association's Executive Committee on Jan. 1; David L. Erickson, director, Lincoln, Neb., Dept. of Public Works and Utilities, a Life Member who was Nebraska Section director in 1944–47 and a Fuller Awardee in 1941; Lloyd D. Knapp, commissioner, Milwaukee Dept. of Public Works; and Roy W. Morse, Seattle city engineer, Fuller Awardee in 1955, and currently chairman of the Resources Division.

Other recipients of the honor were: John Lambie, county engineer, Los Angeles County; Rear Admiral Eugene J. Peltier, chief of the Navy Bureau of Yards and Docks; Glenn C. Richards, commissioner, Detroit Dept. of Public Works; Paul R. Screvane, commissioner, New York City Dept. of Sanitation; Bertram D. Tallamy, federal highway administrator, US Bureau of Public Roads; and Rex M. Whitton, chief engineer, Missouri Highway Dept.

Station WDH Winnipeg, a combination of two 40-mil gal reservoirs and a 60-mgd (Imp.) pumping station, the largest fully automatic pumping station in Canada, was officially opened on Oct. 21. The "WDH," of course, is W. D. "Bill" Hurst, city engineer and AWWA stalwart, for whom the new installation was named. Officially, of course, it is the "W. D. Hurst Pumping Station and Reservoir System."

(*Continued on page 40 P&R*)

for Public Water Fluoridation

Sodium Silicofluoride – 99%
(Powder)

Sodium Fluoride – 98%
(Powder or Granular)

Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY
100 Church Street, New York 7, N. Y.

AA QUALITY

AFTER 12 YEARS IN 1959 OF RESEARCH AND 45,000 OPEN-CLOSE TESTS, THE MUELLER® ORISEAL® CURB VALVE HAS GONE TO WORK. AND ON THE JOB, AS IN THE TESTS, THE ORISEAL HAS PROVEN LEAKPROOF IN SPITE OF REPEATED USE OR PROLONGED IDLENESS. THE "TEFLON"* COATED PLUG RETAINS ALL ITS LUBRICATING QUALITIES IN ALL CONDITIONS. EVEN THE 2" ORISEAL VALVE IS OPERATED WITH JUST A 12" WRENCH—UNDER 125 P.S.I. ONCE INSTALLED, THE ORISEAL SELDOM NEEDS ATTENTION—THE LINE WILL PROBABLY BE REPLACED BEFORE THE ORISEAL WILL REQUIRE SERVICING!

WRITE FOR MORE FACTS ON THE ORISEAL CURB VALVE OR ASK YOUR MUELLER REPRESENTATIVE.

(Continued from page 38 P&R)

Defection, not disinfection, is the first procedure to which a new 48-in. water pipeline from a reservoir in Red China to Hong Kong territory has been subject. And the free residual was 100 disaffected communists who escaped by crawling through the line. No loss of head, but considerable loss of face, was involved.

Another hose dive of the type that puzzled home gardeners from coast to coast several times in the past 5 years has now been reported at Detroit. The hose involved is a 50-ft length of plastic tubing owned by a Mrs. Virginia (well, yes) Binge of 20067 Alcoy. Mrs. Binge's 5-year-old daughter, Carolyn, put the hose in a sand pit in the backyard one day to dampen the sand; next thing she knew it was heading for China. She tried to pull it out. She couldn't. She called her mother. Her mother tried to pull it out. It wouldn't come. Her mother called her brother. Her mother's brother tried to pull it out. It didn't budge. Her mother's brother tried to dig it out. By the time the excavation was 4 ft deep, Detroit *Times* photographers were on hand to record the phenomenon. Next day, when 10 ft of hose had disappeared, they took more pictures. Then they left, leaving the story up in the . . . well, unfinished . . . with the question: "Where do hoses go when hoses go?"

We're not satisfied to leave it there, but we shall have to wait until the

(Continued on page 42 P&R)

HYDRAULIC CALCULATOR

For the determination of friction loss, flow, velocity, pipe size, "C" value, and 1.85 h/Q factor. Based on Williams and Hazen formula. Consists of two circular plastic discs and indicator arm. Pipe sizes range from 4" to 72". Overall size of calculator is 6". Instruction booklet included.

For immediate delivery, send $6.00 to

Robert E. Martin
Consulting Engineer
5402 Preston Highway
Louisville 13, Kentucky

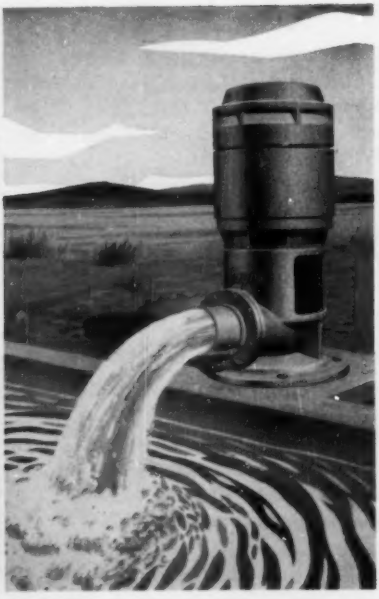
DARLEY MAGNETIC DIPPING NEEDLE

$17.50

with 3 section telescoping handle $22.25

Write Today for 100-Page Catalog

W. S. DARLEY & CO.
Chicago 12



WATER WATER

With A Layne Drilled Well Layne knows where the water-bearing formations are located. Knowing *where* to drill is half of the success—knowing *how* is the other half. In drilling a straight well experience counts. You get a good, producing well when you specify a Layne drilled well.

With A Layne Vertical Turbine Pump Whatever the pumping requirement, there's a Layne pump to meet any pumping conditions. Layne Vertical Turbine Pumps come in a wide range of sizes and capacities, delivering 30 to 20,000 GPM and requiring from 4 to 42 inch well casings.

LAYNE OFFERS COMPLETE WATER SERVICE: Initial Surveys • explorations • recommendations • site selection • foundation and soil-sampling • well drilling • well casing and screen • pump design, manufacture and installation • construction of water systems • maintenance and service • chemical treatment of water wells • water treatment—all backed by Layne Research. Layne services do not replace, but coordinate with the services of consulting, plant and city engineers.

Layne — World's Largest Water Developers

LAYNE & BOWLER, INC., MEMPHIS

General Offices and Factory, Memphis 8, Tenn.

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

Sales Representatives in Major Cities

(Continued from page 40 P&R)

AWWA meeting in Detroit next June to make a personal investigation. Of course, if we can't find 20067 Alcoy then, we shall have to assume that Mrs. Binge forgot to detach the hose from the sill cock. All of which reminds us to rush a note to Gerry Remus, general manager of the water department, warning him to be ready to break the service connection on short notice lest he lose his whole system.

E. S. Dulin, chairman of the board of Byron Jackson, division of Borg-Warner Corp., has retired after 31 years of service with the firm. He had been president from 1929 to 1958 and board chairman since 1945.

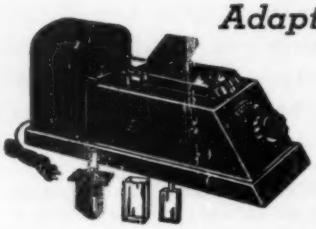
Bright ideas in valves and hydrants have been reported recently from El Segundo, Calif., where the public works department paints its valve covers with "reflecting iridescent paint" to make them easy to find, especially during nighttime when streets may be flooded by broken hydrants; and from Rensselaer, N.Y., where hydrants have received a coating of phosphorescent yellow so that they will stand out in the dark. Then, too, there is Scotchlite.

'Pure Water Group Meets' was the newspaper headline which featured the recent 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia. All of which should

(Continued on page 44 P&R)

KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.

Doughnut in the sky

The Graver Aquatore* — the first new design in elevated storage tanks in over a quarter century—obsoletes conventional tank design for service in residential areas, parks and wherever else appearance is important.

Engineers and public officials can now provide a dramatic, soundly-engineered means of water storage, while eliminating the unsightly tie rods and struts necessary with the usual type of tank. This feat of Graver engineering skill can be built to hold from one-quarter million to three million gallons of water . . . its sleek, steel column can house pumps and other equipment . . . and it costs substantially less to maintain than conventional tanks.

To learn about this water storage tank that will be seen more and more on the skyline, write us today.

In Schererville, Indiana this Graver Aquatore is already a landmark . . . and a tribute to the engineers and officials who specified it.

*Aquatore—Aqua: Latin for water
tore: an engineering term for a
doughnut-shaped object.

Graver

ONE OF THE UNION TANK CAR COMPANIES

Graver Tank & Mfg. Co.
EAST CHICAGO, INDIANA
PLANTS AND OFFICES ACROSS AMERICA

(*Continued from page 42 P&R*)

demonstrate how public relations–consciousness can carry an organization from the ridiculous to the sublime in just a year. Last fall, the Federation of Sewage and Industrial Wastes Associations was fighting off references to the influent of its municipal plants. Now the Water Pollution Control Federation may have trouble living with the pristine characterization of the effluent of its plants. Where, we wonder, does that leave AWWA?

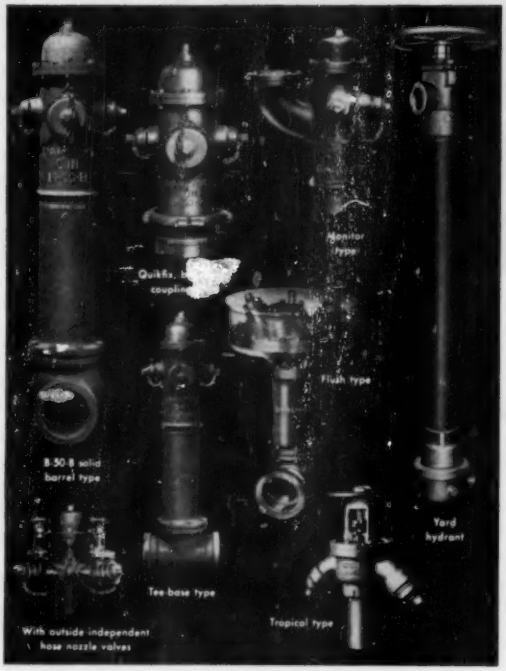
Arthur T. Luce, vice-president of Utilities & Industries Corp. (formerly New York Water Service Corp.), retired on Oct. 31, after 34 years of service with the company and its predecessors. A member of the Association since 1919, he is a Life Member

Thomas R. Komline (right), president, Komline-Sanderson Engineering Corp., Peapack, N.J., was sworn in as assistant director for mobilization planning, Water & Sewerage Industry & Utilities Div., by BDSA Administrator William A. White Sr. After his temporary service, he will be a member of the National Defense Executive Reserve.

(*Continued on page 46 P&R*)

DARLING HYDRANTS

provide exactly the right type for special or unusual service needs



Above you see some of the many types of hydrants in the complete Darling line. With this wide selection, your system can include *exactly* the right types for special or unusual needs . . . all with unmatched Darling quality.

Darling's unique B-50-B design provides *ball-bearing* operation combined with "O" ring seals. This provides a packless, dry-top hydrant with no packing gland maintenance. Operating threads and bearings *stay* lubricated and water can't reach them.

Write us for complete information. Or we'll gladly have a Darling engineer call to discuss your needs.

DARLING VALVES

DARLING VALVE & MANUFACTURING CO.

Williamsport 23, Pa.

Manufactured in Canada by
The Canada Valve & Hydrant Co., Ltd., Brantford 7, Ontario

A Symbol of Quality
FOR WATER SERVICE PRODUCTS
HAYS

MODEL B TAPPING MACHINE
TAPPING MACHINES
One of a complete line of Water Service Products
GENERAL PRODUCTS DIVISION
HAYS MFG. CO.
ERIE, PA.

(*Continued from page 44 P&R*)

and a past-president of the New York Section. He will continue work as a consultant from his new address at Plainfield Rd., Metuchen, N.J.

Donald McCord Baker, consulting engineer, died Oct. 1, 1960, in Los Angeles. After receiving a B.S. degree in civil engineering in 1911, from the University of California (Berkeley), he was employed by the US Indian Irrigation Service until 1917. He then worked from 1917 to 1924 as a hydraulic engineer for the California Water Commission. In 1924 he became a consulting engineer in Los Angeles and joined the firm of Ruscardon Engineers, as a partner, in 1942. In 1954 he returned to private practice as a consultant.

A member of AWWA since 1934, he was also a fellow of the American Geographical Society and active in ASCE and the American Association of Engineers.

Frederick A. Hoeren, office manager for Lee T. Purcell & Co., consulting engineers, died August 8, 1960, at West Orange, N.J. Prior to retirement in 1958, he had been employed for 35 years with the North Jersey District Water Supply Commission, completing his service as secretary to the chief engineer. He was an AWWA member since 1945.

Thurlow C. Nelson, chairman, New Jersey State Water Policy & Supply Council, died Sep. 12, 1960, at Cape May Court House (N.J.), a casualty of Hurricane Donna. He was 69 years old. Born at Highland Park, N.J., he received his B.S. and M.S. degrees from Rutgers University and his Ph.D.

(*Continued on page 48 P&R*)

FIRST

first off-shore sulphur production in the

world will move through Reilly-coated lines

Seven miles off Grand Isle, Louisiana, sulphur will be raised by the Freeport Sulphur Company from a mine 2,000 feet below the ocean floor. Reilly Hot Coal Tar Enamels—Hot Service Enamel with HS X-1 Primer—applied by Pipe Line Service Corporation—will protect delivery lines to shore installations against salt water and other corrosive elements. Inquire at any Reilly Sales Office.

REILLY TAR & CHEMICAL CORP

1615 MERCHANTS BANK BUILDING

INDIANAPOLIS 4, INDIANA

Reilly COAL TAR PRODUCTS

ARMED Protective Coatings

Sales offices in principal cities

(Continued from page 46 P&R)

from the University of Wisconsin. After serving with the Medical Corps in World War I, he joined the Rutgers faculty in 1919 and became head of the zoology department in 1925. He was appointed to the New Jersey Water Supply Commission when it was formed in 1929. In 1945 the commission was succeeded by the present council, with Dr. Nelson as chairman, the post he held at his death. He died as a result of drowning, after he had left his home to secure a small boat, anchored in Delaware Bay during the storm.

The author of more than 100 papers on water supply, hydrobiology, marine biology, and shell fisheries, he was former treasurer, American Society of Zoologists; past-president, National Shell Fisheries Assn.; and past-president, American Society of Limnology and Oceanography. He was corporate representative in AWWA of the New Jersey Department of Conservation.

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

Technical Sales Engineer needed to handle sales of industrial chemicals and active carbon in water treatment and industrial application fields. Sales territory will be assigned after training period in Carbon Service Laboratory in Tyrone, Pennsylvania. Prefer applicant with B.S. degree in chemistry or chemical engineering. Sales experience desirable but not necessary. All replies will be kept confidential. Send resume and salary requirements to Henry F. Laughlin, Manager, Carbon Technical Service Laboratory, West Virginia Pulp and Paper Company, Tyrone, Pennsylvania.

City of Milwaukee. Mechanical engineer (water). $7215 to $8473. $300 additional for professional registration. Salary now under study for 1961. Mechanical engineering graduates with four years of experience. Registered professional engineer or certificate as an engineer in training. Appointee must become resident of city. Apply immediately to Examining Division, City Service Commission, Room 701, City Hall, Milwaukee 2, Wisconsin.

SALES ENGINEER

In municipal and public utility field. Established, fast growing international company with headquarters in New York doing specialty construction in the pipeline field for water, sewage, and industrial clients. Need experienced and mature sales representative on West Coast to contact municipalities, consulting engineers, and private industry in five states. Area is already producing. Right man to become district manager and build and direct his own organization. Background should include engineering and sales, and acquaintanceship with water utility personnel a prerequisite. Good base salary and commission plus expenses for man who can take over the territory. Reply with resume to Box 0121A, Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Filter Sand and Gravel

Well Washed and Carefully Graded to Any Specification.

Prompt Shipment in Bulk or in Bags of 100 lb. Each

Inquiries Solicited

NORTHERN GRAVEL COMPANY

P. O. Box 307 Muscatine, Iowa

microstraining INSTALLATIONS FROM COAST TO COAST

MICROSTRAINING®, as an economical aid to better water for more people, is becoming widely accepted by water supply engineers.

Since 1956 over 20 installations have been put in operation or are under construction, treating a total of more than 120 mgd.

For details of the process and of installations in the U. S., write:

Glenfield & Kennedy, Inc.
275 Halstead Avenue
Harrison, New York
Telephone Tennyson 5-2552

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

Three Penn Center Plaza Philadelphia 2, Pa.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

AWWA STANDARDS

for Water Works Materials

Compiled, approved and published by your Association to meet your needs.

Send for list of publications.

American Water Works Association, Inc.
2 Park Avenue New York 16, N.Y.

AYRES, LEWIS, NORRIS & MAY

Consulting Engineers

Louis E. Ayres — Robert Norris
George E. Lewis — Donald C. May
Stuart B. Maynard — Homer J. Hayward

Waterworks, Sewerage, Electric Power

500 Wolverine Building, Ann Arbor, Michigan

BLACK & VEATCH

Consulting Engineers

1500 Meadow Lake Parkway,
Kansas City 14, Missouri

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal, Gas, Valuations, Special Investigations and Reports

BLACK AND ASSOCIATES, INC.
BLACK LABORATORIES, INC.

Engineers and Chemists

Water, Sewerage, Hydrology, Waste Treatment
Complete Laboratory Services

700 S. E. 3rd St. Gainesville, Fla.

CLINTON BOGERT ENGINEERS

Consultants

Clinton L. Bogert — Ivan L. Bogert
Donald M. Ditmars — Robert A. Lincoln
Charles A. Manganaro — William Martin

Water & Sewage Works — Incinerators
Drainage — Flood Control
Highways and Bridges — Airfields

145 East 32nd Street, New York 16, N. Y.

Bowe, Albertson & Associates

Engineers

Water and Sewage Works
Industrial Wastes
Refuse Disposal
Valuations
Laboratory Service

75 West Street New York 6, N.Y. — 1000 Farmington Ave. West Hartford 7, Conn.

Brockway, Weber & Brockway

Engineers, Incorporated

George S. Brockway — Roy E. Weber
George R. Brockway

Staff

E. L. Fitzgerald — Charles A. Anderson
Robert E. Owen — Ben E. Whittington
Thomas A. Clark — Ernest L. Greene
Thomas R. Demery

Civil, Structural, Sanitary, Municipal, Electrical, Land Planning

West Palm Beach, Florida Ft. Pierce, Florida

BROWN AND CALDWELL

Civil and Chemical Engineers

Water—Sewage—Industrial Waste
Consultation—Design—Operation
Chemical and Bacteriological Laboratories

66 Mint Street San Francisco 3

Professional Services

BUCK, SEIFERT AND JOST

Consulting Engineers

WATER SUPPLY—SEWAGE DISPOSAL—
HYDRAULIC DEVELOPMENTS

Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management, Chemical and Biological Laboratories

112 E. 19th St., New York 3, N. Y.

BURGESS & NIPLE

Consulting Engineers

(Established 1908)

Water Supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Laboratory Municipal engineering
Supervision

2015 W. Fifth Ave. Columbus 12, Ohio

BURNS & McDONNELL

Engineers—Architects—Consultants

4600 E. 63rd St. Trafficway
Kansas City 41, Missouri

JAMES M. CAIRD

Established 1898

C. E. CLIFTON, H. A. BENNETT

Chemist and Bacteriologist

WATER ANALYSIS
TESTS OF FILTER PLANTS

Cannon Bldg. Troy, N. Y.

CAMP, DRESSER & McKEE

Consulting Engineers

Water Works, Water Treatment,
Sewerage and Wastes Disposal,
Flood Control

Investigations, Reports, Design
Supervision, Research, Development

18 Tremont St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION

Consulting Civil Engineers

Dillsburg, Pennsylvania, U.S.A.

THE CHESTER ENGINEERS

Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants—Incineration—Gas Systems
Valuations—Rates—Management
Laboratory—City Planning

601 Suismon Street
Pittsburgh 12, Penna.

CHAS. W. COLE & SON

Engineers and Architects

3600 E. Jefferson Blvd. South Bend, Indiana
2112 W. Jefferson St. Joliet, Illinois

CONSOER, TOWNSEND & ASSOCIATES

Consulting Engineers

Sewage treatment, sewers, storm drainage, flood control — Water supply and treatment — Highway and bridges — Airports — Urban renewal — Electric and gas transmisson lines — Rate studies, surveys and valuations — Industrial and institutional buildings.

360 East Grand Avenue Chicago 11, Illinois

DAY & ZIMMERMANN, INC.

Consulting Engineers

Valuations
Feasibility Studies & Reports
Rate Cases & Financial Studies
Supervisory Consulting Service

1700 Sansom St. Philadelphia 3, Pa.

Professional Services

Fay, Spofford & Thorndike, Inc.

Engineers

Water Supply and Distribution — Drainage
Sewerage and Sewage Treatment—Incinerators
Airports — Bridges — Express Highways

Investigations Reports Valuations
Designs Supervision of Construction

11 Beacon St., Boston 8, Massachusetts

GREELEY AND HANSEN

Engineers

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

14 E. Jackson Blvd., Chicago 4

FINKBEINER, PETTIS & STROUT

Consulting Engineers

Water Supply, Water Treatment,
Sewerage, Sewage Treatment,
Bridges, Highways & Expressways

2130 Madison Avenue Toledo 2, Ohio

GROUND WATER ASSOCIATES

Consulting Hydrologists and Engineers

Investigations, Reports and Recommendations on Underground Water Supplies. Preparation of Plans and Specifications.

Box 480 JEfferson 6-0494
Norman, Oklahoma

FROMHERZ ENGINEERS

Structural—Civil—Municipal
Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Highways & Streets
Investigations; Reports; Plans and Specifications; Supervision

New Orleans

WILLIAM F. GUYTON & ASSOCIATES

Consulting Ground-Water Hydrologists

Underground Water Supplies
Investigations, Reports, Advice

307 W. 12th St.
Austin 1, Texas
Phone: GR-7-7165

GANNETT FLEMING CORDDRY & CARPENTER, Inc.

Engineers

Water Works—Sewerage
Industrial Wastes—Garbage Disposal
Roads—Airports—Bridges—Flood Control
Town Planning—Appraisals
Investigations & Reports

Harrisburg, Pa. Philadelphia, Pa.
Pittsburgh, Pa. Daytona Beach, Fla.

HASKINS, RIDDLE & SHARP

Consulting Engineers

Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction, Appraisals, Valuations, Rate Studies

1009 Baltimore Avenue Kansas City 5, Mo.

GIBBS & HILL, INC.

Consulting Engineers

Water Supply and Treatment
Industrial and Municipal Waste Treatment
Electric Power and Transmission
Transportation and Communication

Pennsylvania Station New York 1, New York

HAVENS & EMERSON

A. A. Burger H. H. Moseley
J. W. Avery F. S. Palocsay
E. S. Ordway G. H. Replanalp
A. M. Mock S. H. Sutton
F. C. Tolles, Consultant

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations—Laboratories

Leader Bldg. Woolworth Bldg.
CLEVELAND 14 NEW YORK 7

Professional Services

HAZEN AND SAWYER

Engineers

Richard Hazen Alfred W. Sawyer
H. E. Hudson, Jr.

Water and Sewage Works
Industrial Waste Disposal
Drainage and Flood Control

360 Lexington Ave. New York 17, N.Y.

Items for Your Library

The latest edition of AWWA's publication list includes information on how you can save money through the use of Publication Discount Coupons.

American Water Works Association, Inc.
2 Park Avenue New York 16, N.Y.

ANGUS D. HENDERSON

Consulting Engineers

Angus D. Henderson Thomas J. Casey

Water Supply and Sanitation

330 Winthrop St. Westbury, New York
210-07—29th Ave. Bayside, New York

THE JENNINGS-LAWRENCE CO.

Civil & Municipal Engineers
Consultants

Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction

1392 King Avenue Columbus 12, Ohio

H. G. Holzmacher & Associates

Consulting Engineers

H. G. Holzmacher
R. G. Holzmacher S. C. McLendon

Municipal Engineering
Water Supply & Treatment
Sewerage & Treatment
Water Analysis Laboratory

66 W. Marie Street, Hicksville, L. I., New York

JONES, HENRY & WILLIAMS

Consulting Sanitary Engineers

Water Works
Sewerage & Treatment
Waste Disposal

2000 West Central Avenue Toledo 6, Ohio

HORNER & SHIFRIN

Consulting Engineers

E. E. Bloss V. C. Lischer

Airports, Sewerage & Drainage, Hydrology, Sewage & Industrial Waste Treatment, Water Supply & Treatment, Paving, Structures, Industry Engineering Services

1221 Locust Street St. Louis 3, Mo.

HARRY J. KEELING

Consulting Engineer

Electrical—Mechanical—Corrosion

Investigations—Reports—Advisory Service
Mobile radio communication systems;
Special mechanical design problems;
Soil corrosion, Electrolysis,
Cathodic protection
of buried or submerged metal surfaces.

1780 S. Robertson Blvd. Los Angeles 35, Calif.

ROBERT W. HUNT CO.

Inspection Engineers

(Established 1888)

Inspection and Test at Point of Origin of Pumps, Tanks, Conduit, Pipe and Accessories

810 S. Clinton St.
Chicago 7, Ill.
and Principal Mfg. Centers

KENNEDY ENGINEERS

Richard R. Kennedy Robert M. Kennedy

Investigation—Design
Water Supply Water Purification
Sewage and Waste Treatment
Water Reclamation

604 Mission St., San Francisco 5
Tacoma Los Angeles Salt Lake City

Professional Services

DEAN S. KINGMAN
Consulting Engineer

Water Works
Sewerage & Treatment

1907 University Avenue
Palo Alto, California

METCALF & EDDY
Engineers

Water, Sewage, Drainage, Refuse
and Industrial Wastes Problems
Airports Valuations
Laboratory

Statler Building
Boston 16

MORRIS KNOWLES INC.
Engineers

Water Supply and Purification,
Sewerage and Sewage Disposal,
Industrial Wastes, Valuations,
Laboratory, City Planning

Park Building Pittsburgh 22, Pa.

JAMES M. MONTGOMERY
Consulting Engineers, Inc.

Water Supply—Water Purification
Sewerage—Sewage and Waste Treatment
Flood Control—Drainage
Valuations—Rates
Investigations—Design—Operation

535 E. Walnut St. Pasadena, Calif.

KOEBIG & KOEBIG
Consulting Engineers Since 1910

Investigations, Reports, Designs
Water Supply & Water Treatment
Sewerage & Sewage Treatment
Municipal Engineering

3242 W. Eighth St. Los Angeles 5, Calif.

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers

Sewage Treatment—Water Supply
Incineration—Drainage
Industrial Waste Treatment
Appraisals

327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

LEGGETTE, BRASHEARS & GRAHAM
Consulting Ground Water Geologists

Water Supply
Dewatering
Recharging

Salt Water Problems
Investigations
Reports

551 Fifth Avenue New York 17, N. Y.

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS
Civil and Sanitary Engineers

Water, Sewage, Drainage and
Industrial Waste Problems.

Structures — Power — Transportation

165 Broadway New York 6, N. Y.

Look to the Journal Advertising Pages

for guidance when you require professional services or water works products. A "Buyers' Guide" appears in the final pages of this issue.

American Water Works Association, Inc.
2 Park Avenue New York 16, N. Y.

MALCOLM PIRNIE ENGINEERS

MALCOLM PIRNIE
ERNEST W. WHITLOCK
ROBERT D. MITCHELL
CARL A. ARENANDER
MALCOLM PIRNIE, JR.
ALFRED C. LEONARD

MUNICIPAL AND INDUSTRIAL
Water Supply—Water Treatment
Sewage and Waste Treatment
Drainage—Rates—Refuse Disposal

25 W. 43rd St. New York 36, N.Y.
2910 Grand Central Ave. Tampa 9, Fla.

Professional Services

THE PITOMETER ASSOCIATES, INC.

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement & Special Hydraulic Investigations

50 Church Street New York

RIPPLE & HOWE, INC.

Consulting Engineers

V. A. Vaseen B. V. Howe

Appraisals—Reports
Design—Supervision

Water Works Systems, Filtration and Softening Plants, Reservoirs, and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports

833—23rd St., Denver 5, Colo.

Professional Cards in the JOURNAL AWWA

A must for water supply consultants

Reserve your space now

American Water Works Association, Inc.
2 Park Avenue New York 16, N.Y.

ROBERT AND COMPANY ASSOCIATES

Engineering Division

Power Plants Water Sewage Plants
Airports Industrial Plants
Docks and Terminal Facilities
Reports Investigations

96 Poplar Street, Atlanta, Georgia

LEE T. PURCELL

Consulting Engineer

Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation

Analytical Laboratories

36 De Grasse St. Paterson 1, N. J.

RUSSELL & AXON

Consulting Engineers

Civil—Sanitary—Structural
Industrial—Electrical
Rate Investigations

408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

RADER AND ASSOCIATES

Engineers and Architects

Water Supply, Treatment and Distribution
Sewers and Sewage Treatment
Investigations, Reports, Plans
Supervision of Construction and Operations
Aerial Photography, Photogrammetry

The First National Bank Building, Miami 32, Florida
1025 Connecticut Ave. N. W.
Washington 6, D. C.

SERVIS, VAN DOREN & HAZARD

Engineers—Architects

Investigations · Design · Supervision of Construction · Appraisals

Water · Sewage · Streets · Expressways · Highways · Bridges · Foundations · Airports · Flood Control · Drainage · Aerial Surveys · Site Planning · Urban Subdivisions · Industrial Facilities Electrical · Mechanical

2910 Topeka Blvd. Topeka, Kansas

THOMAS M. RIDDICK & ASSOCIATES

Consulting Engineers and Chemists

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses

369 E. 149th St. New York 55, N.Y.
MOtt Haven 5-2424

J. E. SIRRINE COMPANY

Engineers Since 1902

GREENVILLE, SOUTH CAROLINA

Design, Reports, Consultations
Water Supply and Treatment
Sewage and Industrial Waste Treatment
Stream Pollution Surveys
Chemical and Bacteriological Analyses

SMITH AND GILLESPIE

Consulting Engineers

MUNICIPAL UTILITIES
AND PUBLIC WORKS

Complete Engineering Services

JACKSONVILLE, FLORIDA

ROY F. WESTON, INC.

Engineers—Biologists—Chemists

Water—Sewage—Industrial Wastes
Stream pollution—Air pollution

Surveys—Research—Development—Process Engineering—Plans and Specifications—Operation Supervision—Analyses—Evaluations and Reports

Newtown Square, Pa.

STANLEY ENGINEERING COMPANY

Consulting Engineers

Hershey Building, Muscatine, Ia.
208 S. LaSalle St., Chicago 4, Ill.
1154 Hanna Building, Cleveland 15, Ohio

WESTON & SAMPSON

Consulting Engineers

Water Supply and Purification; Sewerage, Sewage and Industrial Wastes Treatment. Reports, Designs, Supervision of Construction and Operation; Valuations.
Chemical and Bacteriological Analyses

14 Beacon Street, Boston 8, Mass.

ALDEN E. STILSON & ASSOCIATES

(Limited)
Consulting Engineers

Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports

245 N. High St., Columbus, Ohio
75 Public Square, Cleveland 13, Ohio

WHITMAN & HOWARD

Engineers
(Est. 1869)

Investigations, Designs, Estimates, Reports, Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 Broad St., Boston, Mass.

WATER SERVICE LABORATORIES, INC.

Chemical Engineers

Specialists in Water Treatment
Consulting and Technical Services

Main Office: 615 W. 131 St., N. Y. 27, N. Y.
Offices also in: Phila., Wash., & Richmond

WHITMAN, REQUARDT & ASSOCIATES

Engineers *Consultants*

Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans
Supervision, Appraisals

1304 St. Paul St., Baltimore 2, Md.

J. STEPHEN WATKINS

J. S. Watkins G. R. Watkins

Consulting Engineers

Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.

446 East High Street, Lexington, Kentucky
Branch Offices
5402 Preston Highway, Louisville 13, Kentucky
107 Hale Street, Charleston, W. Va.

WILLING WATER

Public Relations Consultant

Willing Water is available in blocked electrotypes, newspaper mats, decals, and novelties for use in building public and personnel good will.

Send for catalog and price list

American Water Works Association
2 Park Avenue, New York 16, N. Y.

R. KENNETH WEEKS

ENGINEERS

Designers • *Consultants*

Water Supply and Purification
Sewerage and Sewage Treatment
Investigations and Reports
Supervision of Construction

Streets and Highways

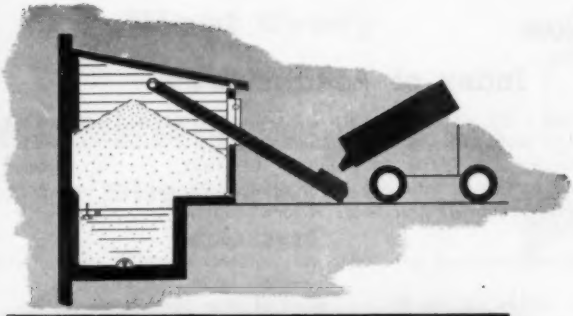
6165 E. Sewells Point Road, Norfolk 13, Va.

WILSEY, HAM & BLAIR

Engineers and Planners

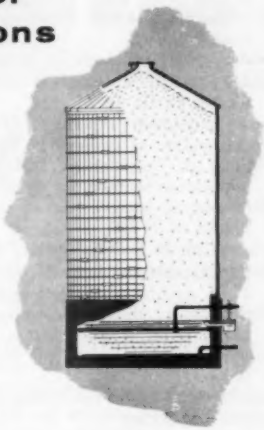
Investigation and Design
Water Supply, Treatment and Distribution
Utilities Rate and Valuation Studies
Sewage Treatment and Disposal
Airports, Municipal Works and City Planning

111 Rollins Road, Millbrae, California
800 W. Colorado Blvd., Los Angeles 41, Calif.



BRINE LEVEL

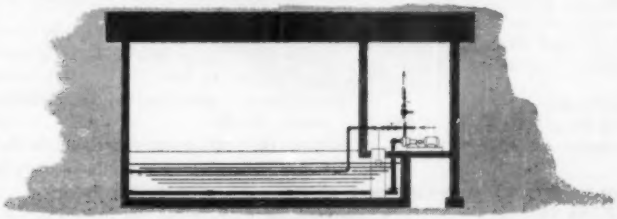
How it can affect design of water softening installations



What's the best brine level for a 500-gallon-per-hour salt dissolver? Your answer is bound to influence the type of dissolver construction needed, as well as the cost of operating the equipment. The lower the level, the less expense there will be in waterproofing the bottom portion of the dissolver. But too low a level can seriously reduce brine-making efficiency, and thus boost brine-making costs.

It is essential, therefore, to reach the best compromise between original construction cost and subsequent operating expense by specifying the correct brine level. Here's where International Salt Company is ready to help. 50 years of experience and continuing research in all phases of salt handling and brine production make International the leading authority on matters concerning salt purchase, storage and dissolving for regenerating ion exchangers. This knowledge is especially valuable in view of the ever-growing amounts of brine being used today.

Service and research are the extras in STERLING SALT



INTERNATIONAL SALT COMPANY, CLARKS SUMMIT, PA. • **Sales Offices:** Boston, Mass. • Buffalo, N. Y. Charlotte, N. C. • Chicago, Ill. • Cincinnati, O. • Detroit, Mich. • Newark, N. J. • New Orleans, La. New York, N. Y. • Philadelphia, Pa. • Pittsburgh, Pa. • St. Louis, Mo.

Condensation

Index of Abstracts

Page numbers refer to P&R section of Journal. Letters immediately preceding page numbers refer to month of issue, using following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November. All subjects and page numbers in boldface type indicate first pages of topic sections.

Acids; neutralization of, with powdered carbonates, Ap 74
Actinomycetes; marine; studies on, Au 84
Aeration; uses of, in water treatment, Jl 62
Air conditioners; water-cooled; control of corrosion and scale in, Au 86
Africa; Ethiopia; water supply problems in, S 78
French Somaliland; water supply problems in, S 78
water supply problems in, N 64, S 76
Alcohol; fatty; evaporation reduction by use of, Ja 70, Ja 72
Algae; blue-green; control of, Mr 78
concentration of cesium-137 by, Jl 78
estimating populations of; inverted-microscope method for, S 84
influence of bacteria on radiophosphorus uptake of, S 100
studies of, in polluted water, Mr 76
Alkalinity; determination of, in sea water, F 74
Alkyl benzene sulfonate; colorimetric determination of, Jl 66
Aluminum; determination of, Ap 78, Jl 66, S 88
corrosion of alloys containing, Je 84, S 94
studies on pitting of, S 94
Amines; use of, for corrosion control, Oc 86
Ammonia; determination of, F 76, Ap 70
Ammonium molybdate; phosphate determination with, F 64
Apparatus; sampling; types of, Oc 74, Oc 76
Aquatic Organisms, Au 64
accumulation of radioisotopes by, N 98
infestations of, in polluted streams, My 76
Artemia salina; oxygen consumption studies on, Au 64
Atomic energy; *see* Radio-
Austria; pollution of rural supplies in, S 74
water use in foundaries of, S 62

Bacteria; coliform; culture media studies on, Ap 84, Au 72, Au 84
differentiation of, Ja 76
Bacteria; coliform (*contd.*); effect of chilling on, Ja 76
effect of other bacteria on, Au 70
effect of storage on counts of, S 98
enumeration of, Au 72
movement of, through porous media, Mr 82
presence of, in domestic supplies, Au 80
in farm supplies, S 98
in river water, Ja 78
corrosive effect of, on stainless steel, My 106
culture media, studies on, Ja 78
enteric; identification of, S 102
survival and multiplication of, S 102
test for, Au 72
effect of ionic environment on, Au 76
effect of photo- and chemosynthesis on, Au 78
effect of surfactants on, Ap 82
gram-negative; fixation of nitrogen by, Ap 80
influence of, on radiophosphorus uptake of algae, S 100
marine; development of medium for, Ja 74
nitrate-reducing; studies of, Ap 80, S 100
oxidation of benzole by, Ap 82
Paratyphoid; selective enrichment medium for, Au 80
Pseudomonas fluorescens; identification of, S 100
Salmonella; determination of quotient for, Au 74
isolation studies on, Ja 76, S 100
survival of, in ground water, Au 74
viability of, Ja 76
Streptococci; detection of, in drinking water, Au 76
sulfate-reducing; enumeration of, Ja 76
Thiobacillus; utilization of thiocyanate by, Au 76
Bactericidal rays; study on, Jl 92
Bacteriology, Ja 74, Ap 80, Au 70, S 98

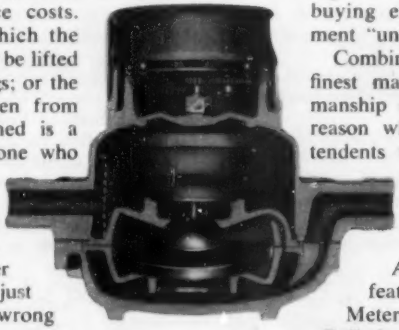
(*Continued on page 60 P&R*)

What Every WATER SUPERINTENDENT Should Know About

AMERICAN METERS

Simplicity

Unequalled simplicity and accessibility of working parts are features of American Meters that reduce maintenance costs. The ease with which the internal gears may be lifted from their bearings; or the disc chamber taken from its seat and opened is a revelation to anyone who has not seen it. And, best of all, you can't put the parts of an American Meter together incorrectly. They just won't fit in the wrong place.



American Meters have full interchangeability of *individual* parts, which permits the low cost rebuilding of worn meters without buying expensive replacement "unit assemblies".

Combine all this with the finest materials and workmanship and you have the reason why water superintendents who know American Meters continue to purchase more, year after year.

All the cost-saving features of American Meters are described in Bulletin 58. We will be glad to mail you a copy on request.

BUFFALO METER COMPANY
INCORPORATED
Subsidiary of American Meter Co., Inc.
2914 Main Street • • Buffalo 14, New York

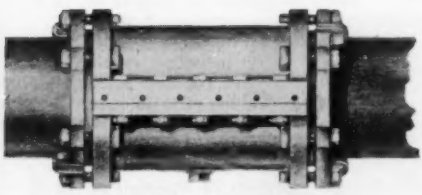
(*Continued from page 58 P&R*)

Belgium; Hautes Fagnes; studies of humic material in water of, Oc 80
problem of radioactive wastes in, Jl 70
pollution control in, Mr 74
water use for coal production in, S 62
Benzole; bacterial oxidation of, Ap 82
Bicarbonate; limitations of p and m values in determination of, Ap 80
Biochemical oxygen demand; inadequacy of, as pollution indicator, Mr 76
studies of, in lakes, Oc 78
BOD; *see* Biochemical oxygen demand
Boilers; characteristic curves for, My 100
control of copper deposition in, My 92
effect of surfactants on scale formation in, S 66
theory of corrosion in, My 104
Boilers and Feedwater, My 92
Borate; determination of, in sea water, F 74

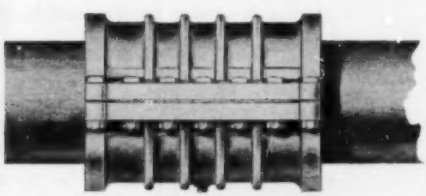
Cadmium; rapid detection method for, F 76
Calcium; determination of, F 64, F 66, Ap 72, Oc 74
fluoride toxicity in presence of, Ja 62
Calcium chloride; behavior of, in boilers, My 96
Calcium hydroxide; behavior of, in boilers, My 96
Carbonate; limitations of p and m values in determination of, Ap 80
powdered; neutralization of acid waters with, Ap 74
Carbon dioxide; determination of, F 70, Ap 70
free; titrimetric determination of, Ap 74
Carbon-14; age assessment of ground water by, Ap 92
direct-plating method for assay of, S 88
Carbonic acid; titrimetric determination of, Ap 74
Cathodic protection; control of corrosion by, Je 74, Je 86, S 98
Cesium-137; concentration of, by algae, Jl 78
Ceylon; presence of coliform bacteria in water supplies of, Au 80
Channels; solution of flow equations for, Oc 68
studies of flow in, Oc 62, Oc 64
Chemical Analysis, Ap 66, Oc 78
Chemical Feeding, Conditioning, and Sedimentation, S 82
Chloride; determination of, F 64, Ap 72, Oc 68
hygienic limit for; in drinking water, Ja 62
prevention of boiler damage by, My 92
Chlorination; biologic effects of, Jl 94
free residual; desirability of, for surface water, Jl 94
Chlorine; action of, on enteric viruses, Ja 74
biologic effect of, Jl 62
disinfection of swimming pools with, Ap 96
evaluation of methods of application of, Ja 74
reactions of, in chlorination, Jl 94
Chlorine dioxide; apparatus for continuous production of, Ap 82
determination of, in treated waters, Ap 78
use of, at Basel, Switzerland, Jl 94
Chloropicrin; colorimetric determination of, Oc 68
Chromium; toxicity studies of, N 82
Ciliates; ecological studies of, Au 66
Coagulation; measurement of, Jl 66
Coal mining; water use in, S 62
Condensers; corrosion and scale prevention in, My 106, Je 74, Au 86
Conservation; *see also* Evaporation control
industrial-water; dewatering of mill wastes for, Mr 78
Cooling water; corrosion inhibitors for, Au 86, S 94
treatment of, for polymetallic systems, S 98
Copper; determination of, F 68
poisoning of vending machine beverages by, Ja 64
studies of corrosion of, S 94, S 96
Corrosion, My 104, Je 74, Oc 86, S 94
automatic control of, in steam lines, Oc 88
boiler; costs of treatment against, S 98
theory of, My 104
condenser; control of, My 106
problem of, Au 86
cooling system; treatment of water for, S 94, S 98
effects of flow mechanics on, Au 88
prevention of, by spray coatings, Je 76
stainless steel; effect of bacteria on, My 106
Crayfish; sodium uptake by, Au 64
Cross connections; enteritis epidemic caused by, Ja 64
hygienic aspect of, N 64
Crustaceans; fresh-water; resistance of, to sodium chromate, Au 64
salinity tolerance studies on, Au 66
Cyanide; determination of, Ap 70
poisoning of drinking water by, S 76

Degradation; biochemical; significance of, in stream pollution, Mr 76

(*Continued on page 62 P&R*)



Mechanical Joint Repair Sleeve



Bell (Hub) End Repair Sleeve

INSTALL A SMITH SLEEVE

Smith Repair Sleeves are the answer to permanently repairing and quickly returning broken and cracked piping to service. Two types of Smith Repair Sleeves are available for installation on standard classes of cast iron pipe. Smith Mechanical Joint Repair Sleeves are produced in sizes 4" thru 12"; Smith Bell (Hub) End in sizes 4" thru 48". Unskilled labor can speedily install Smith Mechanical Joint Repair Sleeves even in wet excavations. Bell End Repair Sleeves are most frequently installed with caulked lead joints. Smith Repair Sleeves reenforce the broken — cracked pipe and their service life equals the life of the pipe.

63

FIRE HYDRANTS VALVES SINCE 1894

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

(*Continued from page 60 P&R*)

Deionization; *see* Demineralization; Ion exchange; Saline-Water Conversion
Demand; irrigation; calculation of, My 102
Demineralization; *see also* Hardness; Softening; Saline-Water Conversion; Ion exchange
Dental caries; *see also* Fluoridation
prevention of, by fluoridation, N 84, N 86
studies on, N 82
Desulfovibrio; enumeration of, Ja 76
Detergents; ABS; colorimetric determination of, Oc 70
anionic; chloroform extraction method for, Oc 74
studies on, in water and sewage treatment, My 70, My 72
Deuterium oxide; determination of, Ap 66
Dimethyldioxane; toxicity studies on, in water, My 80
Disasters; sanitation during, N 66
Disease; epidemic; historical survey of, N 66
wild-animal; ecological studies of, N 82
Disinfection, Ja 72, Jl 92, Oc 84
comparison of methods of, Jl 64
Distillation; brown-coal; apparatus for analysis of water from, Ap 82
Dysentery; Boeblingen, Germany, outbreak of, N 66

Electrodialysis; saline-water conversion by, Ap 86
Electrolysis; use of, for chlorination, Oc 84
Enteritis; epidemic of, at Shreveport, La., Ja 64
Evaporation; effect of wind on, My 104
reduction of, by monolayers, Ja 72, My 102, N 82
Evaporation Control, Ja 70
Eyes; irritation of, by swimming pool water, Ap 96

Fatty acids; effects of, on reservoirs, N 82
Feedwater; *see also* Boilers and Feedwater
carbon dioxide determination in, F 70
demineralization of, Ap 88
phosphoric acid determination in, Ap 70
removal of oxygen from, My 92
tablet tests for, My 98
Filters; horizontal; use of, for small supplies, Jl 62
suspended; use of, in swimming pools, Ap 96
Fish; accumulation of radioisotopes by, N 98
effects of trinitrophenol on, Au 66
Flocculation; measurement of, Jl 66
method of, for clay suspensions, S 82
removal of viruses by, Ja 78, S 102
Floods; hygienic problems during, Ja 68
Florida; Jacksonville; ground water survey at, Ap 94
Flow; effects of, on corrosion, Au 88
filtration; study of, Jl 88
measurement of, My 102
open-channel; solution of equations for, Oc 68
pipeline; measurement of, Oc 64
radioactive measurement of, Ap 82
river; effect of channel roughness on, Jl 90
studies of, in channels, Oc 62
turbulent; theory of, Oc 62
underground; studies of, Ap 92, My 102
theory of, Ap 94
Fluoridation, N 82
Fluoride; determination of, Ap 82
effect of calcium on toxicity of, Ja 62
effect of, on corrosion, S 96
evolumetric estimation of, S 88
feeding of, in individual supplies, N 88
maintenance of constant levels of, N 86
natural; mottling of tooth enamel by, N 86
physiologic and hygienic effects of, N 88
stannous and sodium; effectiveness of, in caries reduction, N 90
Fluorine; effects of ingestion of, Ja 62
spectrophotometric determination of, Ap 66
Fluorosis; study of, N 90
Food; water treatment for manufacture of, S 66
Foreign Water Supplies, S 76; *see also entries under specific countries*
Formaldehyde; hygienic limit for; in water, Ja 64
Foundries; water use in, S 62
France; Nice; use of ozonation at, Jl 92
Freezing; saline-water conversion by, Ap 90
Friction; cyclone separator, Oc 62
Fulvic acids; determination of, Oc 68

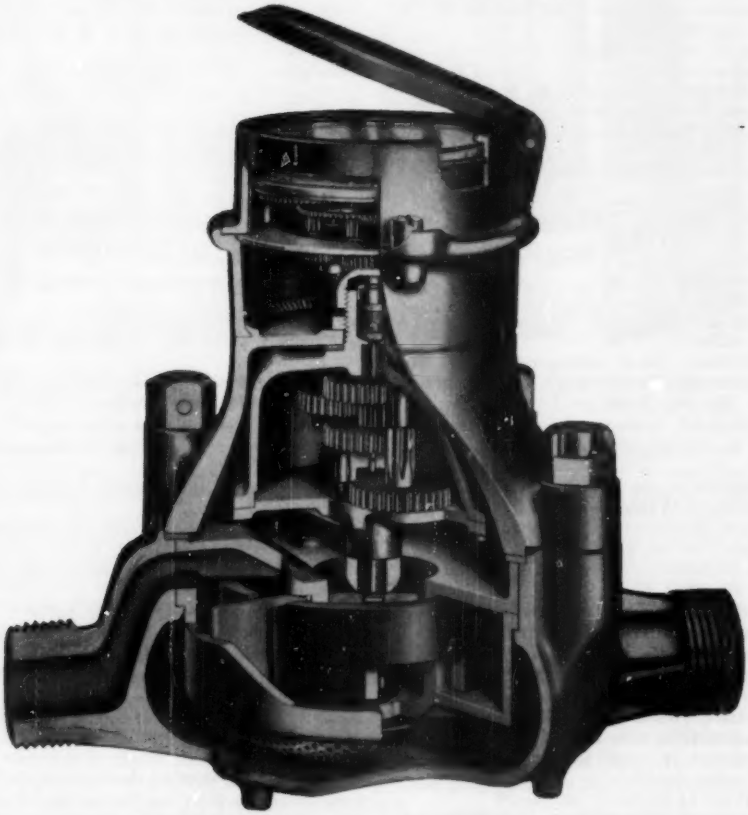
Germany; Hamburg; contamination of harbor at, My 72
industrial water use in, S 62
Rhine-Westphalian region; water supply problems of, S 78
West Berlin; radioactivity of water supply of, Jl 74
Glycosides; use of, for identification of enteric bacteria, S 102
Great Britain; Kitt Green; industrial water use at, S 64
North Wales; studies of coliform counts in, S 98
Winfred Heath; radioactive-waste disposal at, N 98

(*Continued on page 64 P&R*)

specify

CALMET

- all-bronze, split case
- perfectly balanced oscillating piston
- exclusive frost-proof bolt design



WORTHINGTON

CALMET METER DIVISION

2301 SO. MAIN • FORT WORTH, TEXAS

(*Continued from page 62 P&R*)

Ground Water; Ap 92, S 90
age assessment of, Ap 92
analysis of movement of, S 92
calculation of level reductions of, Jl 88
Jacksonville, Fla., survey of, Ap 94
hazard to, from underground nuclear explosions, S 76, S 92
measurement of flow of, Jl 88
location methods for, Ap 92
method for analysis of, Ap 72
nonsteady flow of, My 102
protection of, against liquid pollution, My 78
studies of movement and flow of, Ap 92, Ap 94, S 92
study of contamination of, S 74
Hardness; determination of, Ap 72, Ap 76
Health and Hygiene, Ja 62, N 64
Heavy water; *see* Deuterium oxide
Hepatitis; ground water pollution as cause of, Ja 64
Hexadecanol; evaporation reduction with, My 102
Horizontal-filter wells; experiences with, S 92
Hungary; water supply development in, S 78
Hydraulics Oc 62
Hydrazine; feedwater treatment with, My 96
Hydrogen; dissolved; colorimetric determination of, S 86
Hydrology; use of radioisotopes in, Jl 88
Hydrology, Conservation, and Irrigation, My 102, Jl 88
Hydroxide; limitations of p and m values in determination of, Ap 80

Industrial wastes; *see* Wastes
Industrial Water Use, S 62
Iodide; determination of, Ap 74
Iodine; use of, as water disinfectant, Ja 72
Ion exchange; conversion of saline water by, Ap 84
determination of trace elements by, Ap 78
drinking water softening by, Je 72
feedwater demineralization by, Ap 86
mixed-bed; use of, for treating water for washing semiconductors, S 72
nitrate removal by, N 78
radioactivity removal by, Ap 92
removal of metal ions by, at high flow rates, Ap 92
review of literature on, Ap 88
treatment of condensate by, in nuclear power stations, S 70
units and terms used in, Je 72
Iron; removal of, Je 72, Jl 64
Irrigation; calculation of demands for, My 102
Isoprene; toxicity studies on, My 80
Isotopes; *see* Radioisotopes

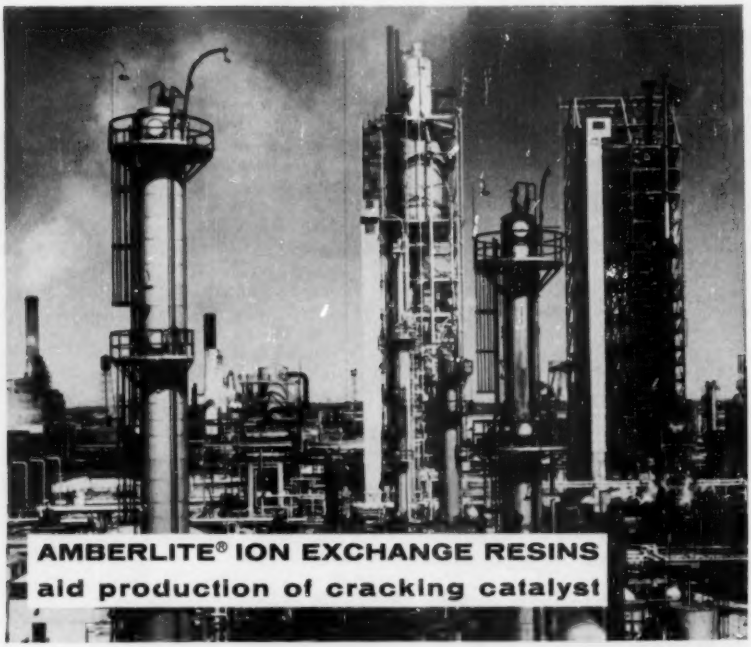
Jacksonville, Fla.; ground water survey at, Ap 94

Laboratory and Field Methods, F 64, Ap 82, Jl 64, Oc 68, S 84
Lakes; study of biochemical oxygen demand in, Oc 78
Lead; cathodic protection of, Je 74
corrosion resistance of alloys of, Je 84
dissolution of, in presence of phosphate, N 80
Legislation; pollution control, Mr 74
Leptospirosis; epidemiological studies of, N 72
Lime; protective action of, in paints, Je 74
Louisiana; Shreveport; enteritis epidemic at, Ja 64

Magnesium; corrosion of alloys of, Je 84
determination of, F 66, Ap 72, Oc 74
salt water corrosion of, Je 80
Manganese; occurrence and removal of, in reservoirs, Je 72
Membrane; electrodialysis, Ap 88
selectively permeable; preparation of, Ap 86
Membrane filters; limitations of, for counting viable bacteria, Au 76
nutrient cardboards used with, Ap 84
Mercury electrode; oxygen determination with, Ap 68
Meters; pressure differential; developments in, Oc 64
Methemoglobinemia; nitrates in drinking water as cause of, Ja 62, N 74
Mineral water; hygiene of manufacture of, N 66
Molybdenum; determination of, Ap 74
Monobromamine; determination of, Ap 66
Monochloramine; determination of, Ap 66
Monolayers; evaporation control with, Ja 72, My 102
Mussels; control of, by ultrasonic treatment, Au 70

Nannoplankton; counting chamber for, Oc 76
New England; pollution control in, Mr 74
New Jersey; Stony Brook; recovery of box board mill effluent at, S 66
Nitrate; determinations of, S 86
ionic; spot test for, F 74

(*Continued on page 66 P&R*)



The Mobil Oil Company Refinery at Paulsboro, N.J., is a volume producer of catalysts for its Thermofor Catalytic Cracking process. To provide water for catalyst and desiccant manufacturing, Mobil runs 1,492,000 gallons of Delaware River water daily through filters and then a two-bed deionizing system. The treated water is used to prepare chemical solutions, and to wash catalyst beads in one of the final processing steps. Water purity is important, since contaminants could affect the chemical behavior of the catalyst. Mobil's anion exchange units use AMBERLITE IR-45. In over 5 years of service, each cubic foot of this anion exchange resin has treated more than 1,500,000 cubic feet of water. Mobil Oil was one of the pioneers in using ammonia to regenerate AMBERLITE IR-45 in a commercial installation. Switching from caustic soda to ammonia regeneration reduced rinse time as much as 63 percent and cut operational costs substantially.

Other fields in which Rohm & Haas ion exchange resins give efficient service include chemical processing, recovery of metals from ores and waste streams, drug manufacturing, food processing and deionization of boiler water for power generation.
Write for a copy of a recently published paper on ammonia regeneration of a weakly-basic anion resin. Also ask for our 24-page booklet, *If You Use Water.*

Chemicals for Industry
ROHM & HAAS COMPANY
WASHINGTON SQUARE, PHILADELPHIA 5, PA.

(*Continued from page 64 P&R*)

Nitrate (*contd.*); methemoglobinemia caused by Ja 62, N 74
removal of, by ion exchange, N 78
Nitrogen; effect of, on bacteria, Oc 82
fixation of, by gram-negative bacteria, Ap 80
organic; determination of, in sea water, F 76
sources of; for bacterial growth, Ap 80
North Dakota; fluoridation in, N 84
Nutrient disks; use of, in membrane filter method, Ap 84

Ontario; pollution by industrial wastes in, Mr 74
Organic matter; determination of, with permanganate, Oc 70
Overflows; storm water; studies of, Oc 66
Oxidation; metal; general equation for, Je 80
Oxides; formation of, on metals, Je 80
Oxygen; dissolved; colorimetric determination of, S 86
electrode system for measurement of, F 78, Jl 66
hypodermic syringe for determination of, Ap 70
movement of, through sea water, Jl 88
portable analyzer for, Ap 68
tonometric determination of, Ap 70
removal of, from feedwater, My 92
Oxygen demand; determination of, F 78
Ozone; studies of disinfection by, Jl 62, Jl 92, Oc 84

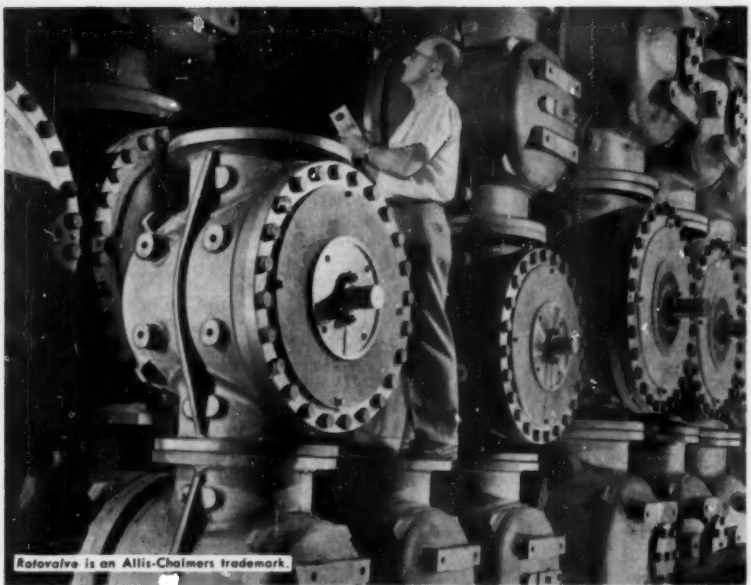
Paints; action of zinc in, Je 76
Paper; treatment of wastes from manufacture of, S 66
Particle size analysis; methods of, S 84
Phenolsulfonic acid; nitrate determination with, S 86
Phosphate; determination of, F 68, Ap 78, S 88
lead dissolution affected by, N 80
occurrence of, in Illinois streams, Mr 80
Phosphoric acid; determination of, in feedwater, Ap 70
Phosphorus; colorimetric determination of, F 64
effect of, on bacteria, Oc 82
radioactive; studies of algal uptake of, S 100
Photosynthesis; effects of, on bacteria, Au 78
Pipe; plastic; hygienic studies of, Ja 68
resistances to flow in; formulas for, Oc 68
steel; cathodic protection of, for carrying sea water, Je 86
Plankton; accumulation of radioisotopes by, N 98
copepod; studies on, Au 66
oxygen consumption studies on, Au 64
uptake of strontium by, S 102
Plastics; hygienic studies of pipe and fittings made of, Ja 68
Poland; Czarna Woda; industrial water conservation at, S 66
water supply development in, S 78
Poliomyelitis; disinfection of water contaminated by, Jl 94
Pollution Control, Mr 74, My 70, S 72
Pollution; chemical; toxicity index for, My 80
formaldehyde as factor in, Ja 64
stream; bacteriologic aspects of, S 74
evaluation of, My 78
mechanism of, My 74
reduction of, Mr 74, My 84
Polonium-210; accumulation of, by fish, N 98
Polyphosphates; well restoration with, Ap 92
Potassium; field determination of, F 78
radioactive; soil radioactivity due to, N 100
Puerto Rico; Ponce; typhoid epidemic at, N 66

Radium; determination of, F 78
Radiation; bactericidal; studies of, Jl 92
nuclear; hazards of, Jl 74
nuclear; human exposure limits for, Jl 74
Radioactive wastes; treatment and disposal of, Mr 86, My 90, N 92, N 94, N 98
Radioactivity, Jl 70, N 92
determination of, in saline water, Jl 66
estimation of stream uptake of, Jl 86
ground water contamination by, S 76
protection of water supplies against, My 88
soil; studies of, N 100
water supply problems caused by, Jl 72
Radioisotopes; accumulation of; by aquatic organisms, N 98
by plants, Jl 76
determination of, Ap 72, Jl 86, S 88
fixation of, in clay sinters, N 94
significance of, in water and waste water, N 100
studies on, in water, My 88
study of ground water movement by, Ap 92, Ap 94, Jl 88
use of, in hydrology, Jl 88
Reactors; decontamination of spent fuel shield water from, Jl 80
problem of waste water from, N 100

(*Continued on page 68 P&R*)

ALLIS-CHALMERS

A-1303



Standard butterfly and ball valves illustrated are also available from stock in a broad range of sizes.

Another Allis-Chalmers time-saving exclusive:

Cone valves "right off the shelf!"

Six to thirty-inch *Rotovalve* units — awaiting your call. Think of the valuable time you save! Typical is the case of a western municipality that recently needed one 24-inch and three 20-inch *Rotovalve* units for their waterworks. Allis-Chalmers assembled all accessories required, completed testing and shipped the valves to customer in less than three weeks! Compare this with the 3 to 6 months normally required by other suppliers for delivery.

Perpetual off-the-shelf inventory of *Rotovalve* units, butterfly and ball valves gives Allis-Chalmers today's only complete rotary valve-stocking program . . . guarantees fastest deliveries to you.

Avoid troublesome, costly delays and get the valves you need to do the job right. For immediate assistance anytime, call your nearby A-C valve representative, district office or write **Allis-Chalmers,** Hydraulic Division, York, Pa.

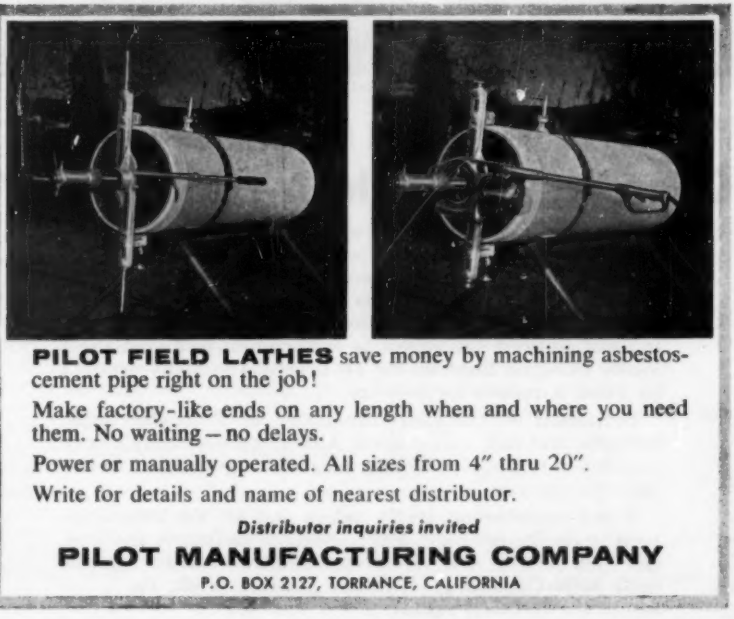
Rotovalve is an Allis-Chalmers trademark.

(*Continued from page 66 P&R*)

Reservoirs; effect of fatty acids on, N 82
pollution control in, Mr 74
Reuse; examples of, in steel industry, S 64
Rural areas; hygienic problems in Ja 64, N 64
risks from fecal pollution in, S 74
Rust; prevention of, by spray coatings, Je 76

Saline water; corrosion of metals in, Je 80
Saline-Water Conversion, Ap 84
Salmonella; food poisoning by, N 80
Sampler; water; battery-operated, Jl 64
Scale; air conditioner; prevention of, Au 86
boiler; control of, My 92, My 96
effect of surfactants on formation of, S 66
condenser; prevention of, Je 74
cooling water; inhibitors for, S 94
Schistosomiasis; epidemiological studies of, N 74, N 78
Sediments; studies of, Oc 84
Semiconductors; washing of; demineralization of water for, S 72
Sewage; calculation of dilution rates for, Mr 78
Shreveport, La.; enteritis epidemic at, Ja 64
Silica; determination of, F 72, S 90
Silver; studies of, for disinfection, Oc 86
Sludge; wash water; treatment and disposa of, My 86
Sodium chromate; resistance of crustaceans to, Au 64
Softening and Iron Removal, Je 72
Solids; suspended; investigation of, in waste water, My 84
South Africa; stream pollution studies in, S 74
Steam; solubility of low-volatility substances in, My 98
Steel; corrosion of, in condenser tubes, Oc 86
Steel industry; water use in, S 64
Strontium; radioactive; separation of, from solutions, N 98
studies of, in reservoirs, My 90
transmission of, to humans, N 98
uptake of, by plankton, S 102
Sulfate; determination of, F 76, Oc 74
Sulfide; determination of, Ap 70, Ap 76
Sulfite; boiler water treatment with, My 96
Sulfur; effect of, on bacteria, Oc 82
Sulfur oxide; determination of, Ap 76

(*Continued on page 70 P&R*)



PILOT FIELD LATHES save money by machining asbestos-cement pipe right on the job!

Make factory-like ends on any length when and where you need them. No waiting – no delays.

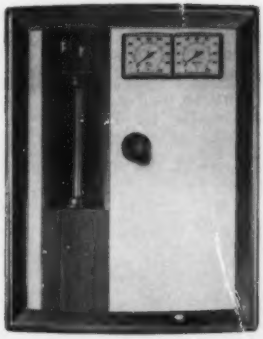
Power or manually operated. All sizes from 4" thru 20".

Write for details and name of nearest distributor.

Distributor inquiries invited

PILOT MANUFACTURING COMPANY

P.O. BOX 2127, TORRANCE, CALIFORNIA



This, believe it or not, is a wall mounted chlorinator. Its attractive appearance is our way of showing how proud we are of the advanced operating parts hidden behind the front panel. For example: This is the first wall mounted chlorinator ever to feature a single stack regulator. Simple, compact appearance belies the fact that it can handle up to 200 pounds per day of chlorine more accurately, dependably, and safely than any other chlorinator with the single exception of its big brothers. It is so completely corrosion-proof in the right places that we have little hope of ever selling replacement units. In short, we have never been happier with any product than we are with the new Series 3600 chlorinators.

Should you wish to order one of these beauties sight-unseen, on our say-so, we can deliver immediately from warehouse stocks across the country. If not, your local F&P field office will gladly demonstrate the 3600 Series at your plant, at your convenience. Call for an appointment. Or, write for complete information in Bulletin 70C3600. Fischer & Porter Company, 1020 Fischer Road, Warminster, Pa.

FP

FISCHER & PORTER COMPANY

INSTRUMENTATION AND CHLORINATION

These MANUFACTURING AFFILIATES carry Fischer & Porter engineering designs to the far corners of the earth: FISCHER & PORTER (CANADA) LTD., DOWNSVIEW, ONTARIO • FISCHER & PORTER LTD., WORKINGTON, CUMBERLAND, ENGLAND • FISCHER & PORTER G.m.b.H., GROSSELLERSHAUSEN, BEI GOTTINGEN, GERMANY • FISCHER & PORTER N.V., KOMEETWEG 11, THE HAGUE, NETHERLANDS • FISCHER & PORTER Pty. LTD., 184 HANNA ST., SOUTH MELBOURNE, VICTORIA, AUSTRALIA.

(*Continued from page 68 P&R*)

Surfactants; effect of, on bacteria, Ap 82
effect of, on boiler scaling, S 66
polyglycolic; determination of, Ap 68
use of; in culture media for bacteria, Ja 74
Sweden; Morbylanga; water use in sugar refining at, S 66
Swimming Pools, Ap 96
Switzerland; Basel; use of chlorine dioxide treatment at, Jl 94
Lake Constance; radioactivity in, Jl 74
St. Gollen; ozonation installation at, Jl 62
Syndets; *see* Detergents

Taste and odor; gas-permeable synthetic pipe as factor in, Ja 68
Thorium; determination of, F 78
Thorium nitrate; volumetric estimation of, S 88
Tooth decay; *see* Dental caries; Fluoridation
Tracers; radioactive; selection of, for investigating ground water movement, Jl 70
Treatment—General, Jl 62
see also under various types of treatment
industrial water, review of, S 72
Trinitrophenol; reactions of fish to, Au 66
Tritium; use of, as ground water tracer, Ap 94
Trout; temperature preferences of, Au 66
Tularemia; transmission of, by water, N 72
Turbidity; studies of, Oc 82
Typhoid; epidemic of; at Ponce, P.R., N 66
in Rumania, N 70

Ultrasonic waves; studies of water disinfection by, Ja 74
use of, for mussel control, Au 70
Ultraviolet radiation; industrial water treatment by, Jl 92
USSR; Moscow; isotopic analysis of water supply at, Ap 72
water supply protection and development in, S 80

Vending machines; copper poisoning from, Ja 64
Viruses; enteric; inactivation of, by chlorine, Ja 74
poliomyelitis; destruction of, by chlorine, Jl 94
removal of, by flocculation, Ja 78, S 102

Wastes; industrial; legislation for control of, Mr 74
problems of, My 84
toxicity index for, My 80
pulp mill; bioassays for control of, My 84
treatment of, My 90
radioactive; treatment and disposal of, Mr 86, Jl 76, Jl 78, Jl 80, Jl 84, S 70
uranium ore refinery; effects of, on receiving waters, Jl 76
zirconium manufacture; toxicity of, Jl 78
Waste water; effects of suspended matter in, My 84
reactor; problems of, N 100
toxic effects of, on stream biota, My 78
Weirs; calibration of, Oc 66, Oc 68
flow equations for, Oc 64
flow measurement by means of, My 102
Well screens; cleaning of, Ap 92
Wells; disinfection of, with calcium hypochlorite, Oc 84
restoration of, Ap 92
yield-depression curves for, S 92
Wells and Ground Water, Ap 92, S 90

Authors of Abstracted Articles

Page numbers refer to P&R section of Journal. Letters in italics immediately preceding page numbers refer to month of issue, in accordance with following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November.

ABDUSSALUM, M., *N* 82
ABRAMS, I. M., *Ap* 92
ACKERS, P., *Oc* 66
ADAMS, H., *Ja* 64
AGRANAT, V. Z., *N* 98
AHRENS, W., *Ja* 68
ALBANO, A., *Jl* 92
ALBERTI, G., *F* 78
ALCOCK, P., *S* 86
ALCOCK, W., *N* 86
ALESKOVSKII, V. B., *Ap* 78
ALTSHULER, L., *N* 66

(*Continued on page 72 P&R*)

Chicago Bridge & Iron Company

Write our nearest office for complete information or estimating figures on steel tanks for municipal service.

Offices

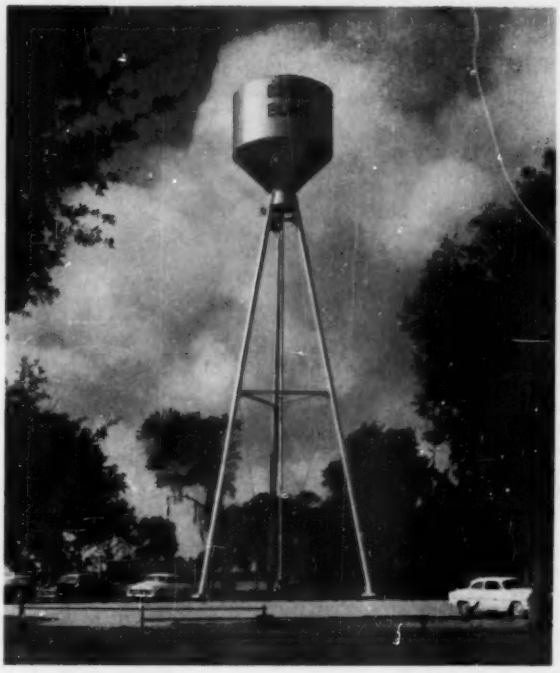
Atlanta
Birmingham
Boston
Chicago
Cleveland
Detroit
Houston
Kansas City
New Orleans
New York
Philadelphia
Pittsburgh
Salt Lake City
San Francisco
Seattle
South Pasadena
Tulsa

Plants

Birmingham
Chicago
Greenville, Pa.
Houston
New Castle, Del.
Salt Lake City

IN CANADA

Horton Steel Works Limited



Efficient and Economical

Horton tripod elevated tanks provide economical gravity water pressure for general service and fire protection in small municipalities. They are built in accordance with AWWA specifications.

The tank is of functional modern design supported on three cylindrical columns. Both the tank and the columns are constructed of steel plates with butt welded joints. The interior and exterior surfaces are smooth and flat. This makes it easy to paint, giving lasting protection and long life.

Tripod elevated tanks are built in capacities from 15,000 to 75,000 gallons. Standard heights to bottom range from 25 feet to 100 feet in the 15–30,000-gallon range and 25 feet to 125 feet in the 40–75,000-gallon range.

(Continued from page 70 P&R)

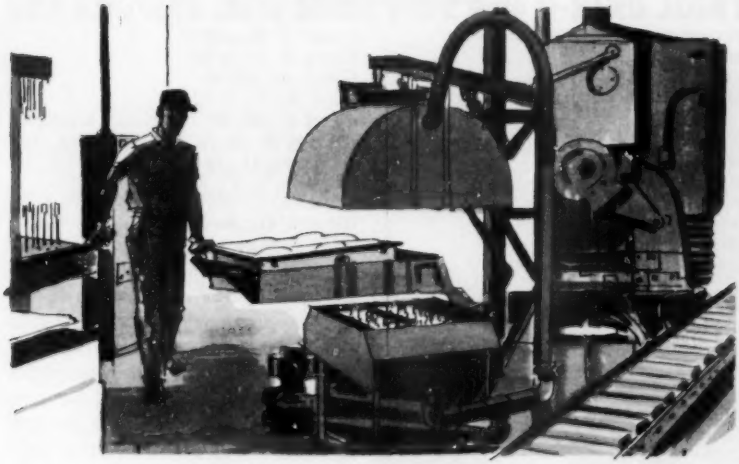
AMPHLETT, C. B., *Mr* 86, *Jl* 80
ANKARA, S. A., *Ap* 92
AOYAMA, Y., *Je* 80
ARMBRUST, H. N., *My* 106
ARMIJO, R., *N* 66
ASSIM, T. H., *Au* 80
AWA, N., *Je* 86
AYLMORE, D. N., *Je* 80

BABCOCK, H. A., *Oc* 68
BAENST, N. D., *Mr* 74
BALICE, A., *N* 80
BARBIERI, V., *Jl* 94
BARKER, N. T., *Ap* 92
BEAN, E. L., *Jl* 92
BEHR, L., *N* 94
BELING, A., *Ap* 84
BELITSKII, A. S., *S* 92
BELL, J., *Oc* 68
BELYAEV, I. I., *S* 82
BENEDEN, G. V., *F* 64, *Jl* 64, *Oc* 80, *Oc* 84
BENEZRA, L., *Ap* 92
BERGER, B. B., *My* 102
BERKOV, A. M., *Jl* 62
BERLO, J., *Ap* 88
BERRY, P., *Ap* 82
BETTINALI, C., *F* 78
BICK, H., *Au* 66
BIEN, G. S., *F* 72
BLAGOVESHCHENSKAYA, N., *N* 72
BLAHO, M., *Oc* 64
BOBY, W. M., *Ap* 86
BOCHEM, J., *Ap* 70
BODAMER, G., *Ap* 88
BOGAN, R. H., *Mr* 76
BOGERS, P. F., *Ap* 88
BOIKO, A. A., *Jl* 92
BORCHARDT, J., *Mr* 76
BOTHWELL, M. R., *Je* 84
BOUILLAUD, R., *Au* 72
BOURNE, H. J., *S* 66
BOWMAN, W., *N* 90
BRAGINA, A. N., *N* 100
BRAITHWAITE, E. R., *Jl* 70
BRAUN, K., *Ja* 64
[illegible]MAN, J. I., *Au* 86
Au 70
S 64
Ap 92
I., *Je* 74
4
66
, *Jl* 88
78, *Je* 72, *N* 80

CALEMBERT, J., *My* 102
CAMERON, J., *Ap* 82
CAMPBELL, H., *S* 88
CAMPOBASSO, J. J., *Je* 88
CARPENTER, J. H., *F* 66
CARRITT, D. E., *F* 78, *Jl* 66
CHAMBON, M., *My* 72
CHANG, S. L., *Ja* 72, *Ja* 78, *S* 102
CHOU, K. S., *Ap* 74
CLARKE, J., *N* 86
COATES, K. B., *S* 86
COHEN, J. M., *S* 72
COLAS, R., *S* 64
COLDWELL, B., *F* 74
COLES, H., *S* 98
CONKLIN, D. B., *S* 86
COOKE, B. A., *Ap* 86
CORNELSON, D., *N* 70
CORNUAT, E., *S* 64
COWSER, K. E., *Jl* 84
COXON, T. L., *My* 74
CREN, E., *S* 84
CULBREATH, M. C., *Jl* 80
CULP, R. L., *Je* 88

DALL, H. E., *Oc* 64
DAMMANN, G., *Au* 72
DANDO, R. A., *Ap* 94
DANEL, P., *Jl* 88
DANIEL, S. S., *F* 68
DAS, M., *F* 66
DAVENPORT, W. H., *S* 94
DAVIES, D. E., *S* 94
DAVIS, J., *Oc* 68
DECARREAUX, J., *S* 64
DEJONGHE, P., *Jl* 70, *Jl* 84
DELAPORTE, A. V., *Mr* 74
DELIUS, I., *N* 78
DE MEIRA, M., *N* 90
DEMPSTER, N. S., *Je* 84, *S* 94
DE SOUSA, H., *N* 90
DICKINSON, B. N., *Ap* 92
DIEDEM, B., *S* 66
DIETRICH, B. H., *Jl* 72, *N* 100
DIETZ, J., *Mr* 80
DIXON, J. M., *Au* 72
DODGE, B. F., *Ap* 88
DOE, P. W., *My* 86
DOHEN, E., *S* 64
DONALD, M., *Oc* 62
DOUDOROFF, P., *My* 84
DOWNING, A. L., *Jl* 62
DRESSLER, R., *Ja* 70
DROBEK, W., *My* 88
DRUCE, R., *S* 98

(Continued on page 74 P&R)



The M & H Spirit

There are those who might believe that a valve is just a valve. They might say: "What's in a name? All valves are made of about the same iron and bronze – so what?"

The answer is that one valve can be better than another because it is more skillfully designed and the men who make it are craftsmen who take greater pride in their work. The honor and honesty of a man – his veracity, fidelity and sincerity – is best shown by his acts.

It is by their daily work at M & H that the attitude of M & H personnel toward M & H products takes on form and substance. We call it the M & H Spirit – and it is an inherent factor in the quality and operating efficiency of an M & H Valve or Hydrant.

Thirty-four years of M & H history proves that an M & H Valve or Hydrant is in a class by itself. Its record of efficient trouble-free service has caused the Company to grow from 60 to 500 employees, with a present annual payroll of over $2,000,000.00. It has so rapidly increased in use throughout the U. S. and foreign lands that M & H Company has become one of the leading industries in its field.

(No. 7 of a Series)

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF WALWORTH

(Continued from page 72 P&R)

Dublyans'kii, V. M., *Ap* 72
Duhoux, M. A., *S* 78
Durham, K., *Ja* 72
Dyadichev, N. R., *S* 102

Edeline, F., *S* 62, *S* 84
Eden, G. E., *Jl* 64
Effenberger, M., *Oc* 74
Ehrmann, H., *Oc* 84
Eliassen, R., *Au* 88
Elipiner, L. I., *Ja* 74
Engel, F. V., *My* 102, *Oc* 64
Engel, H., *S* 100
Entz, B., *Ap* 78
Erdey, L., *F* 64
Eshaya, A. M., *Ap* 88
Etienne, H., *Ap* 68
Etinger-Tulczynska, *Au* 70

Fairbanks, C. W., *Au* 66
Falk, O., *Oc* 64
Farris, C. A., Jr., *My* 92
Feitsma, R., *My* 100
Ferguson, F., *N* 78
Figura, V., *Jl* 84
Fischer, G., *S* 74
Fischer, W. K., *Ap* 82
Flentje, M. E., *Je* 88
Ford, J., *Oc* 76
Fournier, R., *Oc* 68
Francis, R. L., *Ap* 96
Fraser, H. R., *My* 102
Freedman, B., *Ja* 64
Freier, R., *My* 92
Frison, P., *Jl* 92
Fuchs, J., *Jl* 94

Gaase, A., *Ap* 96
Gabbrielli, G., *Ap* 84
Gabovich, R., *N* 84
Gad, G., *Jl* 74, *Jl* 92, *Oc* 74
Gaessler, W., *My* 78
Galloway, E. E., *Oc* 86
Garden, N., *N* 94
Garside, E. T., *Au* 66
Gast, J., *F* 74
Gelberg, A., *Ap* 70
Gilchrist, B. M., *Au* 64
Giunti, G., *Ap* 84
Glastonbury, H., *S* 88
Gleason, H., *N* 66
Goda, T., *My* 74
Goldin, A., *Jl* 66
Goncharova, K., *N* 72
Gossling, B. S., *Au* 76
Gras, E. H., *My* 106
Green, J. H., *Ap* 92
Gregg, S. J., *Je* 80
Grein, A., *Au* 84
Grin, N. V., *N* 82
Griss, G., *Ap* 82
Grundy, F., *Ja* 70, *Ja* 72
Guignard, H., *Je* 72
Guinvarc'h, P., *Jl* 92
Guskova, V. N., *N* 100
Guthof, O., *Au* 72

Habenicht, G., *Ap* 96
Haccius, B., *Ap* 82
Hahn, R., *Jl* 86
Halevy, E., *Jl* 70, *Jl* 88
Hall, R., *Oc* 76
Halliday, J., *Jl* 66
Hammer, L., *S* 76
Hammerton, C., *S* 72
Hanker, J. S., *Ap* 70
Happold, F., *Au* 76
Harding, T. P., *S* 82
Harmeson, R., *Mr* 80
Harris, E. K., *Jl* 86
Harris, W., *N* 86
Harrison, M. E., *My* 76
Harry, H. W., *N* 74
Hatch, A. E., Jr., *Je* 88
Hatch, L. P., *N* 98
Heitmann, H. G., *My* 96
Hermann, E. R., *My* 80
Hernandez, D., *N* 66
Heukelekian, H., *My* 76
Higgins, G. H., *S* 76
Hild, W., *N* 98
Himes, R. C., *Ap* 90
Hluchan, E., *Ap* 82
Hoak, R. D., *My* 84
Hobson, P., *S* 98
Hodgkinson, C., *Mr* 82
Hoemig, H. E., *Ap* 80
Hofmann, E., *Jl* 62
Hogenkamp, H., *Ja* 74
Holland, P., *Ap* 70
Hollo, I., *S* 78
Holluta, J., *Jl* 74
Hoff, W., *Oc* 84
Hopper, S., *Ja* 64
Horner, J. W., *My* 102
Hubert, M. A., *S* 72
Huebner, A., *S* 74
Hulanicki, A., *F* 64
Hublen, T., *Je* 80
Hurst, E. H., *S* 98
Hustler, H. F., *Ap* 96
Hutton, K., *Oc* 66

(Continued on page 76 P&R)

LOS ANGELES *chose* STEEL PIPE *with* O-RING JOINT

Granada Pipeline Unit No. 3, built for the Department of Water & Power, City of Los Angeles, is the first major water pipeline to use "High Strength" steel plate with the new O-ring rubber gasket field joint. This 30,000 foot line through the San Fernando Valley, used 32 foot lengths, 49½ in. diameter pipe with ¼ to ⅜ in. wall thickness. Installation time of the O-ring joint proved to be 90% faster than welded joints and permits deflection up to 2° angle and longitudinal movement of at least one inch without leaking. Final hydrostatic tests showed practically 100% watertight at normal pressure.

. . . every length was hydrostatically tested in the shop to AWWA standards!

STRENGTH
TIGHTNESS
ELASTICITY
ECONOMY
LONG LIFE

. . . these are inherent qualities of fabricated *steel* pipe. Compare *steel* pipe with other types . . . you'll see why "wherever water flows, steel pipes it best." You can always specify *steel* pipe with confidence.

For your copy of the latest steel pipe brochure, write—

STEEL PLATE FABRICATORS ASSOCIATION
105 West Madison Street • Chicago 2, Illinois

STEEL PLATE FABRICATORS ASSOCIATION FOUNDED 1921

(*Continued from page 74 P&R*)

Il'in, D., *N* 98
Indri, E., *Jl* 88
Ineson, J., *S* 92
Ireland, G. H., *S* 66
Ivanov, G., *Ap* 72
Iwasaki, I., *Oc* 68

Jacobs, M. B., *Ap* 76
Jankovits, L., *F* 64
Jannasch, H. W., *Ap* 80
Janowski, A., *F* 64
Jansen, J. C., *Ap* 88
Jansson, O. G., *Je* 74
Jebb, W. H., *Au* 84
Jennings, P., *F* 70
Jensen, C. R., *My* 106
Jepson, W. P., *Je* 80
Johannesson, J. K., *F* 76, *Ap* 66
Johanson, A., *Ja* 70
Jones, C. H., Jr., *My* 105
Jones, G., *Au* 76
Jones, J. D., *Ap* 70
Jong, G. J., *Ap* 88
Jung, W., *Ap* 96

Kanwisher, J. W., *F* 78, *Jl* 66
Karchmer, J. H., *Ap* 68
Katugampola, D. C., *Au* 80
Kaufman, J., *N* 94
Keating, R. J., *S* 66
Keleti, J., *N* 74
Keller, P., *S* 74
Kelly, J. E., *My* 106
Kelly, S., *Ja* 74
Kempe, T., *Jl* 74
Kemula, W., *F* 64
Kerr, J. M., *N* 94
Kipling, C., *S* 84
Kirkbride, T., *Oc* 66
Kirkendall, W. E., *Je* 88
Kiser, R., *Oc* 78
Klenor, P., *S* 66
Klimkina, N. W., *My* 80
Klinge, K., *S* 100
Knapp, W., *S* 76
Knijhnikov, V., *Ja* 62
Knoepp, H., *My* 78
Knotek, Z., *N* 74
Koeck, W., *Jl* 70

(*Continued on page 78 P&R*)

ACTIVATED SILICA SOL
. . . coagulant aid

The "method" of convenience . . .

- **Liquid feed**
- **Quickly speeds floc formation**
- **No delays**

Activated silica sol develops large, rapid settling floc. More impurities are removed. High quality, clear water is produced during exceptionally long filter runs.

N-Sol Processes, employing "N" sodium silicate, are PQ's patented methods for preparing activated silica sol. Licenses are available without royalty fee.

Write for this complete bulletin on the use of sodium silicate for "Raw and Waste Water Treatment".

PHILADELPHIA QUARTZ CO.
1142 Public Ledger Bldg., Philadelphia 6, Pa.

PQ SOLUBLE SILICATES

Associates: Philadelphia Quartz Co. of Calif. Berkeley & Los Angeles, Calif.; Tacoma, Wash.; National Silicates Limited, Toronto & Valleyfield, Canada

Trademarks Reg. U.S. Pat. Off.

PQ Plants: Anderson, Ind.; Baltimore, Md.; Buffalo, N.Y.; Chester, Pa.; Jeffersonville, Ind.; Kansas City, Kan.; Rahway, N.J.; St. Louis, Mo.; Utica, Ill.

very dependable

PATENTED SILICONE STUFFING BOX RING

a name to remember

WATCH DOG

simple to maintain

Offices in principal cities

Split case or frost proof

GAMON METER DIVISION

NEWARK & NEW JERSEY

WORTHINGTON

(Continued from page 76 P&R)

KOEHLE, H., *My* 88
KOESTER, H., *My* 84, *S* 78
KOGAN, M., *S* 80
KONFORTI, N., *Au* 80
KOROVIN, Y. M., *My* 106
KRAJENBRINK, H., *Oc* 62
KRASNOZHEN, D. E., *Je* 74
KRASOVSKY, G. N., *Ja* 62
KRAUS, P., *Ja* 76, *Oc* 76
KRESSMAN, T. R., *Ap* 84
KRIEGER, L., *Ap* 70
KRISTYAK, E., *Au* 86
KRONE, R., *Mr* 82
KRUCHKOVA, E. S., *Ap* 76
KRUSE, H., *N* 66
KUBELKA, V., *My* 84
KUHN, W., *Ap* 70
KULAKOWSKI, A., *S* 66
KUNIN, R., *Ap* 88
KUZNETSOV, S. I., *Au* 78

LAGERSPETZ, K., *Au* 66
LANG, R., *Ap* 92
LAPAGE, G., *N* 82
LAROSE, M. R., *Ap* 92
LAUBUSCH, E. J., *Ap* 96
LAUDE, L., *Je* 72
LAURENT, P. J., *Au* 64
LEBEDEVA, G., *N* 98
LEBOUT, H., *Jl* 92
LEDENT, R., *F* 78
LEFEBVRE, P. H., *Au* 86
LEHMANN, J., *Ja* 74
LEI, C. Y., *Ap* 74
LEIGEOIS, R., *S* 62
LESENYEI, J., *Ap* 74
LESTER, W. F., *Mr* 74
LEUR, D. A., *My* 102
LEWIN, R. A., *S* 102
LEY, J. B., *My* 34
LIEBEN, P., *S* 62
LIEBER, M., *F* 76
LIEBERMAN, J. A., *S* 70
LIESER, K., *N* 98
LINDAHL, P. E., *Au* 66
LISTER, B. A., *My* 90
LORSCH, W. F., *S* 72
LUND, J. W., *S* 84, *Oc* 76

MCARTHUR, I., *Ja* 72
MCCARTHY, J. A., *S* 96
MCCREADY, C. C., *S* 88
MCLEAN, S., *F* 74
MCMULLEN, D. B., *N* 74
MACKENZIE, R. D., *N* 82
MACLEOD, R., *Ja* 74
MAIER, F. J., *N* 86
MAISTRUK, P., *N* 84
MAKINSKII, I. Z., *My* 92
MALEK, Y., *Ja* 76
MALEVSKAYA, I. A., *Ja* 62
MANDERSLOOT, W. G., *Ap* 86
MANN, J., *N* 86
MANNO, P., *Jl* 80
MANSFIELD, W. W., *Ja* 72
MANTHEY, M., *Jl* 92
MARCSTROEM, A., *Au* 66
MAREI, A., *N* 98
MARTINEC, J., *Jl* 90
MASI, A., *N* 66
MASON, J. F., JR., *My* 106
MASSART, R., *My* 96
MASTRORAZIO, F., *S* 94
MATSIDAIRA, C., *F* 76
MAYER, J., *Ap* 82
MAYER, P. G., *Oc* 62
MEGAY, K., *N* 64
MEISSNER, B., *Ap* 82
MELBOURNE, K. V., *Jl* 64
MENON, V., *F* 66
MERRITT, W. F., *Ap* 94
MEYER, R., *Au* 74
MEYERS, S. P., *Au* 84
MEYNELL, G. G., *Ja* 76
MIDDLETON, K. R., *S* 86
MIKHAILOVSKII, B. N., *N* 72
MILLER, F., *Ja* 64
MINER, G. N., *S* 66
MISHRA, I. B., *S* 88
MISSA, L., *My* 96
MONTERIOLO, S., *Ap* 66, *S* 90
MOORE, R., *Jl* 88
MOORE, W. A., *Ap* 78
MOORE, W. L., *Oc* 68
MORGAN, J. H., *Je* 86
MORRIS, H. M., *Oc* 62
MORTON, R., *Jl* 84
MOSER, H., *Jl* 88
MOSKALEV, Y., *N* 98
MOSS, H. V., *My* 72
MOUSTAFA, A., *Oc* 74
MUENNICH, K. O., *Ap* 92
MULLER, A., *Ja* 68
MULLER, A. C., *S* 70
MURPHY, J., *S* 88
MUSTAFIN, I. S., *Ap* 76
MYSELS, K. J., *My* 104

NAMBU, S., *My* 74
NAUMANN, E., *Jl* 62, *Jl* 94
NAZARENKO, I. V., *Ja* 64
NECHAEVA, A., *F* 78

(Continued on page 80 P&R)

"SADDLES ARE FOR HORSES"

. . . not American Cast Iron Pipe!

Too often the first cost of the material is the only factor considered when deciding between cast iron pipe or a substitute. To give sole thought to the cheaper substitute piping is, in a sense, false economy because many times this lower initial cost is misleading and obscures added expenses which must be incurred later. Yes, the first cost may be cheaper . . . but cast iron pipe offers so much more.

Consider tapping. For reliable, economical water service, the tapped main must meet four definite requirements: (1) Have strength to withstand tapping operation; (2) Be of an *easily* tapped material which will assure *uniform* threads; (3) Have strength after being tapped to withstand service conditions; (4) Have threads that will provide tight connections after exposure to service stresses. *Cast iron pipe meets all of these tapping requirements.*

When tapping substitute piping, it is often necessary . . . to employ skilled workmen with special equipment . . . to utilize tapping saddles . . . to use extreme care in order to make a connection that does not leak.

Remember . . . tapping saddles are an extra expense and are *not necessary to make service connections to cast iron pipe.*

AMERICAN CAST IRON PIPE CO.
BIRMINGHAM ALABAMA

SALES OFFICES
New York City • Dallas
Chicago • Kansas City
Minneapolis • Denver
Cleveland • Pittsburgh
Orlando • Birmingham

(Continued from page 78 P&R)

NEIL, J. H., *Mr* 78
NELSON, E., *Jl* 88
NEMEROW, N., *Mr* 74
NEUMAIER, F., *Jl* 88
NEVITT, G., *N* 90
NEWMAN, T. R., *Au* 86
NIETSCH, B., *Ap* 96
NOISETTE, G., *Oc* 82
NOLE, V. F., *S* 94

OBERZILL, W., *Oc* 86
OBI, A. N., *Au* 72
OBRECHT, M., *S* 96
OKABE, S., *Ap* 74
OLIVER-GONZALEZ, J., *N* 78
ONOFREY, E., *Ja* 74
ORLOB, G., *Mr* 82
OSBORN, E., *F* 70

PACKHAM, R. F., *Jl* 66
PADMANABHAN, V., *Oc* 78
PALANGE, R. C., *Jl* 78
PALIN, A. T., *My* 98
PALMER, P. V., *S* 96
PANDELESCU, M., *Ja* 76
PAPPENHAGEN, J. M., *S* 86
PARKER, F. L., *Jl* 84
PATNAIK, D., *S* 88
PEEL, C., *N* 64
PELLETIER, C. A., *Jl* 72
PERRIA, M., *Jl* 94
PERSON, M., *Oc* 68
PETERSON, J. K., *N* 84
PETROVA, A., *N* 98
PETTIT, G. A., *Mr* 78
PIROTTE, J., *Oc* 88
POSEY, C., *Oc* 62
POST, M. A., *Ap* 78
POURBAIX, M., *My* 104
POWELL, R., *Oc* 62
PRATT, D., *Au* 76
PREISTER, M. U., *Je* 88
PREUSS, L. E., *Jl* 74
PROCTOR, M. H., *Ap* 80

QUILL, L., *S* 96
QUINN, W., *Jl* 88

(Continued on page 82 P&R)

WHY USE TWICE THE WATER YOU NEED TO CLEAN FILTER BEDS?

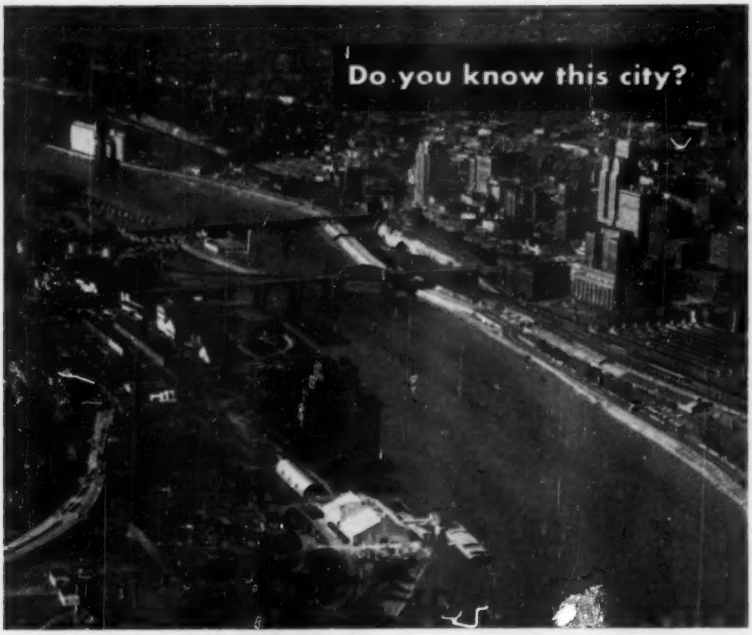
H & T AIR-WATER WASH FILTERS use only half as much water as ordinary systems. Yet the air and water, together, clean the filter bed more completely!

We are the ONLY large, experienced manufacturer of Air-Water Wash Filters. In the past 45 years, we've made hundreds of successful installations. Get the money-saving facts about H & T AIR-WATER WASH FILTERS.

SEND FOR BULLETIN 23-B

H&T SERVICE

HUNGERFORD & TERRY, INC.
Clayton 5, New Jersey

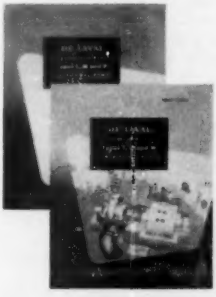


DE LAVAL *water works pumps*

provide vital water supply for...

Minneapolis-St. Paul—dynamic twin cities at the headwaters of the Mississippi. Here, as in most major cities of the United States, De Laval water works pumps are doing a year-in, year-out job, proving their reliability in this vitally important service.

De Laval makes water works pumps with capacities ranging up to 100 million gallons per day to meet all water works requirements.



Write for your copies of De Laval Bulletins 1004 and 1005 giving data on these pumps.

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL491A

(Continued from page 80 P&R)

RAHEEM, A., *Oc* 74
RAKUSHINA, E. I., *Jl* 64
RAPPAPORT, F., *Au* 80
RAPSON, W. H., *Ap* 82
RAVERA, O., *Au* 64
RAYET, R., *Je* 72
REASER, P. B., *Ap* 66
REES, R. L., *My* 92
REININGER, H., *Je* 76
REISH, D. J., *Oc* 76
RESCH, G., *My* 92
REZNIKOV, A., *F* 78
RHEINFURTH, H., *N* 66
RIETEMA, K., *Oc* 62
RILEY, J., *F* 68, *S* 88
RIZK, S., *Ja* 76
ROBERTSON, W. D., *S* 94
ROBINSON, R. H., *S* 86
ROEST, A. C., *Au* 76
ROMEO, A. J., *Au* 88
ROSHARD, H., *Ap* 92
ROSU, I., *Ja* 76
ROZENBERG, L. A., *My* 106
RUFFEL, M. A., *Mr* 78
RYZHOV, N. V., *Jl* 94

SALVATTI, F., *F* 78
SAMOILOV, Y. F., *My* 96
SAMUEL, T., *S* 98
SANDERSON, W., *Ja* 74
SANZOT, E., *My* 78
SAUROV, M., *N* 98
SAY, B., *Oc* 66
SCHAPER, G., *N* 74
SCHEIDEGGER, A. E., *Ap* 94
SCHERRER, A., *Ap* 74
SCHILLMOLLER, C. M., *My* 106
SCHMITT, R. J., *Oc* 86
SCHUBERT, R., *Ja* 76
SCHULZ, F., *Ja* 68
SCHULZE, E., *Oc* 82
SCHUSTER, H. J., *Je* 76
SCHWARTZ, W., *Ja* 68
SEELER, G., *S* 100
SELENKA, F., *Ja* 78
SEYB, E., *My* 92
SHARPE, D., *Oc* 66
SHAW, J., *Au* 64
SHAW, R. S., *S* 74
SHERIDAN, M., *Oc* 62
SHIELDS, H., *S* 94
SHILLING, C. W., *Jl* 74
SHTANNIKOV, E. V., *Jl* 94
SIEMON, H., *Jl* 88
SIL'CHENKO, V., *N* 72
SIMPSON, N., *S* 98
SINE, L., *My* 102
SINHASENI, P., *F* 68
SKINNER, C. E., *Au* 72
SKRINDE, T., *Au* 88
SLACK, J. G., *Oc* 74
SLEZAK, H., *Ap* 96
SMIRNOV, O. K., *My* 96
SMITH, H. G., *S* 100
SMITH, J. M., *N* 92
SMITH, R. A., *Oc* 68
SNAVELY, W., *Jl* 80
SODD, V., *Jl* 66
SORG, L. V., *S* 94
SOUSKE, R., *Je* 76
SPAANDER, P., *Au* 76
SPARGO, P. E., *My* 70
SPITSYN, V. I., *N* 92
SPITZ, G., *N* 86
SQUIRE, W., *Oc* 62
SRIVASCAVA, S., *Oc* 78
STAINSBY, W., *My* 102, *Oc* 64
STAMICARBON, N. V., *Ap* 88
STANGENBERG, M., *Oc* 78
STEHR, E., *My* 72
STEVENSON, M., *S* 88
STIFF, F. R., *Jl* 92
STOLWIJK, J., *Jl* 76
STRAUB, C. P., *Jl* 78, *Jl* 86
STROBEL, J. J., *Ap* 90
STUTZ, R. L., *S* 94
STYRIKOVICH, M. A., *My* 98
SUBBOTIN, F. N., *Ja* 62
SUGAWARA, K., *Ap* 74
SULE, J., *Au* 86
SURENYANTS, Y. S., *Oc* 84
SWANSON, H., *Jl* 78
SZCZENIOWSKI, J., *S* 64

TAIT, J. S., *Au* 66
TANAKA, M., *Ap* 74
TAYLOR, F., *Ap* 82, *N* 86
TAYLOR, F. J., *My* 92
TERASAWA, M., *Je* 84
THATCHER, L., *Oc* 78
THOFERN, E., *N* 64
THOLOMIER, *S* 78
THOMANN, O., *Ap* 74
THOMAS, S., *S* 98
THOMPSON, T., *F* 74
THON, D., *Ap* 84
THORNLEY, J. L., *Au* 86
TIMOTHEE, R., *N* 66
TONG, A., *My* 106
TOOKOS, I., *Ap* 74
TORRICELLI, A., *Jl* 92
TOURNIER, R., *S* 76

(Continued on page 84 P&R)

TRINITY VALLEY

for all cast iron water works fittings

AWWA Standard Bell Spigot Watermain Fittings— 2" through 36".

Ring Tite Fittings 3" through 16" Class 150. Class 100 through 12".

Short Body and Mechanical Joint Watermain Fittings— 2" through 20".

Fluid-Tite Fittings— 3" through 16" Class 150. Class 100 through 12".

Fabricated Piping

Flange Fittings

TRINITY VALLEY IRON AND STEEL COMPANY

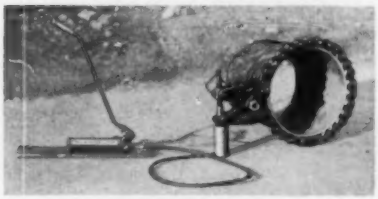
Phone PE 9-1925 Fort Worth, Texas P. O. Box 664

NOW AVAILABLE!

THE WHEELER

"SUPER"

HYDRAULIC PIPE CUTTER

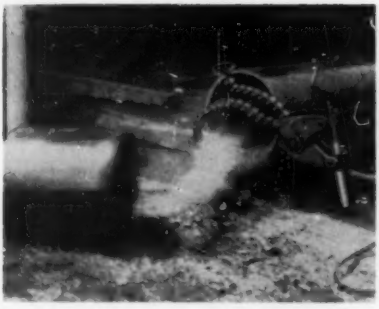


for 10" thru 20"
CAST IRON WATER MAIN

No rotating—all you do is wrap the chain around the pipe, engage it in the cutter's upper jaws, adjust out slack and operate pump.

JUST
SQUEEZE AND POP!

For pipe sizes up to 12" we recommend our Heavy-Duty Hydraulic shown here in the act of cutting a section of large diameter pipe.



The Wheeler Mfg. Corp.

P. O. Box 688
Ashtabula, Ohio

(Continued from page 82 P&R)

TREDGETT, R. G., *Je* 72
TRIPATHY, K., *S* 88
TRUESDALE, G. A., *My* 70
TRYGG, J. E., *Mr* 74
TSIVOGLOU, E. C., *Jl* 76
TSUDA, T., *F* 76
TUSZKO, A., *S* 78
TYLER, C. P., *Ap* 68

ULANOVSKII, I. B., *My* 106

VAJDA, J., *S* 78
VANDERVELDEN, F., *My* 104
VAN DONGEN TORMAN, P., *My* 105
VAN LANDINGHAM, J. W., *Ap* 72
VARGA, J., *S* 90
VELTEN, R., *Jl* 66
VIETEN, G. C., *Ja* 68
VISINTIN, B., *Ap* 66, *S* 90
VOGEL, J. C., *Ap* 92
VOLKER, A., *My* 102
VOLLENWEIDER, R. A., *Au* 64

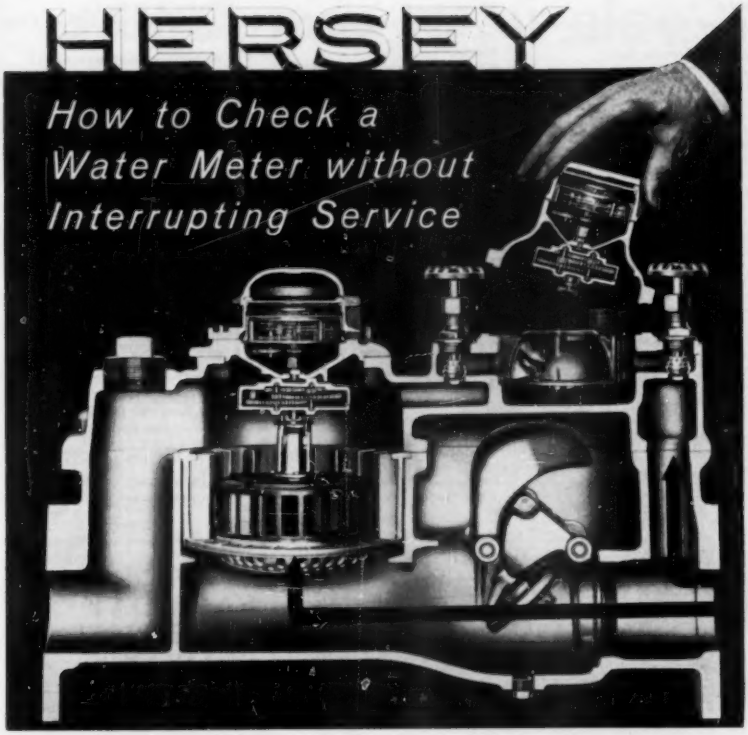
WALDEMEYER, T., *S* 92
WALKER, W. J., *S* 82
WARD, W. M., *Oc* 74
WARREN, C. E., *My* 84
WASSINK, E., *Jl* 76
WATT, W. D., *S* 100
WEBER, G., *Ja* 64, *Ja* 76
WEBSTER, H. L., *Jl* 66
WENDT, I., *Jl* 88
WESTERHOF, A., *Jl* 76
WHITMORE, R. L., *Jl* 70
WHITTAKER, R. H., *Au* 66
WIDEMANN, O., *Jl* 94
WIELAND, T., *Ap* 82
WILLIAMS, L., *Jl* 78
WILLINGER, H., *S* 74
WILSON, A. L., *Oc* 68
WILSON, P. W., *Ap* 80
WILSON, W. L., *Mr* 74
WIRTH, L., *S* 70
WISE, W. S., *Mr* 74
WISNIEWSKI, T. F., *My* 78
WITTEN, B., *Ap* 70
WITTER, D., *N* 90
WOLOCHOW, H., *Au* 76
WORTHEN, L. R., *S* 102
WUSTENBERG, J., *N* 64

YAKIMENKO, I. M., *Ap* 72
YAMAMATO, Y., *Je* 86
YOSHIZAWA, S., *My* 100

ZHOGOVA, V. M., *My* 90
ZIEMINSKA, S., *Ja* 78
ZIMMERMAN, W., *N* 66

HERSEY

How to Check a Water Meter without Interrupting Service



4" size shown above

That's a Hersey Compound Water Meter having its by-pass meter checked - *without shutting off the main line.* This is one reason these meters are the No. 1 choice when both large and small rates of flow are to be measured. Another reason is the high degree of accuracy obtained by using the extremely sensitive Hersey conical disc type meter on the by-pass.

A special feature of the Hersey Compound Meter is the exclusive swing type lever valve which diverts small flows through the by-pass but, when opened by a large demand, offers no resistance to the flow of water.

These meters are available in sizes from 2" to 10" inclusive (2", 3", 4", 6" all bronze cases—8" and 10" galvanized iron cases). Write for more facts.

Hersey-Sparling
Meter Company
HERSEY PRODUCTS
DEDHAM, MASSACHUSETTS

Branches: Atlanta, Boston, Chicago, Cleveland, Dallas, Denver, Kansas City, Mo., Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Seattle.

Index of Advertisers' Products

Activated Carbon:
Industrial Chemical Sales Div.
Permutit Co.

Activated Silica Generators:
B-I-F Industries, Inc.—Omega
Wallace & Tiernan Inc.

Aerators (Air Diffusers):
American Well Works
Carborundum Co.
Eimco Corp., The
General Filter Co.
Permutit Co.
Walker Process Equipment, Inc.

Air Compressors:
Allis-Chalmers Mfg. Co.
Worthington Corp.

Alum (Sulfate of Alumina):
American Cyanamid Co., Process Chemicals Dept.
General Chemical Div., Allied Chemical Corp.

Ammonia, Anhydrous:
General Chemical Div., Allied Chemical Corp.
Jones Chemicals, Inc.

Ammoniators:
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Co., Inc.

Ammonium Silicofluoride:
American Agricultural Chemical Co.

Associations, Trade:
American Concrete Pressure Pipe Assn.
Cast Iron Pipe Research Assn.
Steel Plate Fabricators Assn.

Brass Goods:
Anaconda American Brass Co.
Hays Mfg. Co.
Mueller Co.

Brine-Making Equipment:
International Salt Co., Inc.

Calcium Hypochlorite:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.

Carbon Dioxide Generators:
Ozark-Mahoning Co.
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.
Harco Corp.

Cement Mortar Lining:
Centriline Corp.
Halliburton Co.
Southern Pipe Div. of U.S. Industries

Chemical Feed Apparatus:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
F. B. Leopold Co.
Permutit Co.
Precision Chemical Pump Corp.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Chlorine Comparators:
Fischer & Porter Co.
Klett Mfg. Co.
Wallace & Tiernan Inc.

Chlorine, Liquid:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.

Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Dorr-Oliver Inc.
Eimco Corp., The
General Filter Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

PATENTS PENDING

Spherical
SHOCK
TRAP® for
WATER LINES

Eliminate water hammer and pipeline bursting.
Save piping and plant costs with guaranteed surge limits.

PULSCO®

Designed primarily for shut-down or shut-off application, this unit is used in pumping plants, irrigation systems, fire control on rocket test stands, municipal water systems, etc. Of the water interface type, the Pulsco swirl principle reduces pressure and reduces shock and surge resulting from kinetic energy within the pipeline, this by compressing gas within the chamber and by friction through the swirl chamber.

Guarante'd not to recycle, this Pulsco Spherical Shock Trap is built for pressures to 200 PSIG and up. Sizes from 34 to 102 inches diam.

SEND FOR BULLETINS AND APPLICATION DATA SHEET

Representatives in all principal cities

PULSATION CONTROLS CORPORATION

P. O. Box 169, Santa Paula, Calif.
Phone JAckson 5-6641

A FEW CENTS EACH DAY KEEPS RUST AWAY

National Tank Maintenance Corporation as a pioneer in the field of Annual Maintenance can show you how to save money

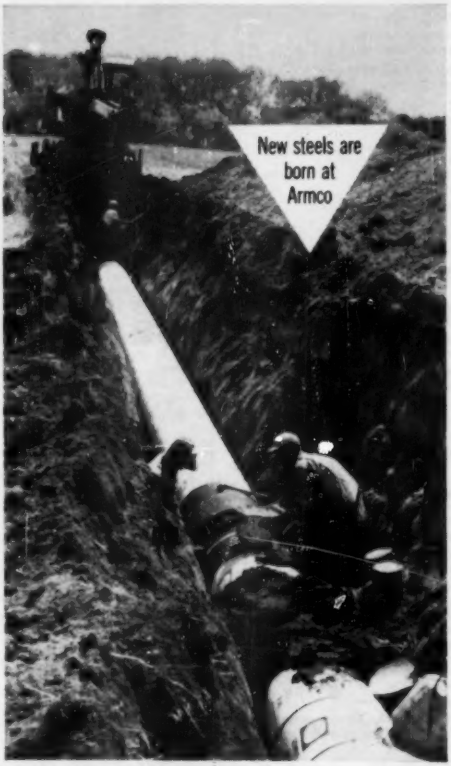
1. **Thorough inspection by qualified inspectors to determine structural, paint and rust conditions.**
2. **Submit recommendations for corrective measures.**
3. **Place your installation in first class condition, complying with requirements of consulting engineers and state health authorities.**
4. **For nominal annual fee service your installation each year.**
5. **Emergency service available at all times.**
6. **Complete performance bond coverage.**

WRITE—WIRE OR TELEPHONE

NATIONAL TANK MAINTENANCE CORP.

1617 Crocker St.
Des Moines, Iowa
CH 3-8094

Aberdeen saves $104,000 with Armco water pipe



When Aberdeen, South Dakota, needed an additional water transmission line to run from the water works to a storage tank inside the city, they used Armco Steel Pipe for the job. Armco's bid to supply 32,290 lineal feet of 24" steel water pipe was $104,068.65 under that of the nearest competitive bidder.

Aberdeen's Mayor, J. Clifton Hurlbert, had this to say about the installation: "This pipe was installed without experiencing any difficulty whatsoever, and all tests proved satisfactory."

This example is only one of many in which Armco Steel Pipe has saved customers time and money. Get complete information on how this pipe can serve *you*. Write to Armco Drainage & Metal Products, Inc., 6840 Curtis Street, Middletown, Ohio.

ARMCO DRAINAGE & METAL PRODUCTS

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation

Coagulant Aids:
Hagan Chemicals & Controls, Inc.
Nalco Chemical Co.
Philadelphia Quartz Co.

Condensers:
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.
Worthington Corp.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Simplex Valve & Meter Co.

Copper Sheets:
Anaconda American Brass Co.

Copper Sulfate:
Tennessee Corp.

Corrosion Control:
Calgon Co.
Harco Corp.
Nalco Chemical Co.
Philadelphia Quartz Co.
Southern Pipe Div. of U.S. Industries

Couplings, Flexible:
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries

Covers, Vault:
Ford Meter Box Co.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engineers and Chemists:
(See Professional Services)

Evaporating Equipment:
Ozark-Mahoning Co.

Excavating Equipment:
Charles Machine Works, Inc.
Eimco Corp., The

Feedwater Treatment:
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
Permutit Co.

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
General Filter Co.
Johns-Manville Corp.
Multi-Metal Wire Cloth Co., Inc.
Northern Gravel Co.
Permutit Co.
Stuart Corp.

Filters, Incl. Feedwater:
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Eimco Corp., The
Permutit Co.
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Eimco Corp., The
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Multi-Metal Wire Cloth Co., Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp., The
General Filter Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.
Olin Mathieson Chemical Corp.
Ozark-Mahoning Co.
Tennessee Corp.

Fluoride Feeders:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Fischer & Porter Co.
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Mueller Co.
Southern Pipe Div. of U.S. Industries

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Photovolt Corp.
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Intake Screens:
Multi-Metal Wire Cloth Co., Inc.

Ion Exchange Materials:
General Filter Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

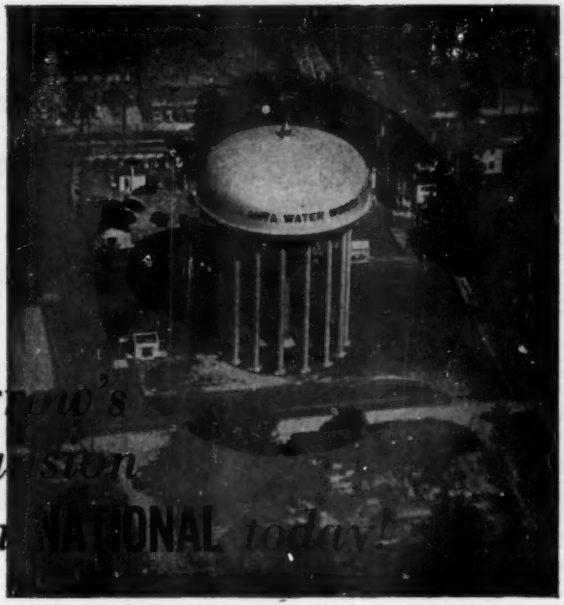
Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Rockwell Mfg. Co.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.



For tomorrow's expansion call in NATIONAL today!

Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains*. When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.

Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.

Write us today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafl., Lima, Peru

Hays Mfg. Co.
Hersey-Sparling Meter Co.
Mueller Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co
Ford Meter Box Co.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Fischer & Porter Co.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

Mixing Equipment:
General Filter Co.
F. B. Leopold Co.

Motors, Electric:
Allis-Chalmers Mfg. Co.
Marathon Electric Mfg. Corp.
Worthington Corp.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Pipe, Asbestos-Cement:
Atlas Asbestos Co. Ltd.
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
Anaconda American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
James B. Clow & Sons
Southern Pipe Div. of U.S. Industries
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
Anaconda American Brass Co.

Pipe, Plastic:
American Hard Rubber Co.
Keasby & Mattison Co.
Morgan Steel Products, Inc.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries

Pipe Cleaning Services:
Ace Pipe Cleaning, Inc.
Centriline Corp.
National Power Rodding Corp.
National Water Main Cleaning Co.
Robinson Pipe Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
American Hard Rubber Co.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Southern Pipe Div. of U.S. Industries

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
Wheeler Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Fischer & Porter Co.
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Eimco Corp., The
General Filter Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
Nalco Chemical Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

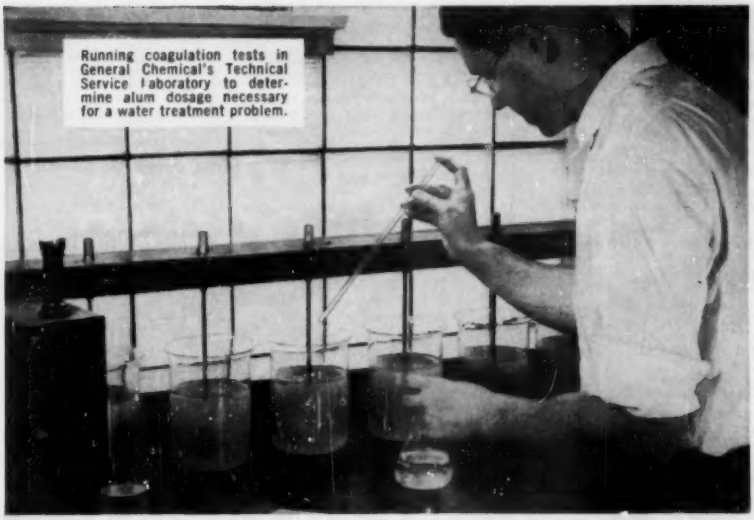
Sodium Silicate:
General Chemical Div., Allied Chemical Corp.
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

Softeners:
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
Nalco Chemical Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.



Running coagulation tests in General Chemical's Technical Service laboratory to determine alum dosage necessary for a water treatment problem.

Another difference in GENERAL CHEMICAL ALUM is TECHNICAL SERVICE

As the country's primary producer of aluminum sulfate, General Chemical constantly helps customers solve technical problems involving the use of alum. Results? Improved efficiency and reduced operating costs for them. Here are some of the services our Technical Service Department offers:

- Supplying basic information helpful in planning design and installation of storing, pumping, metering and feeding facilities.
- Suggesting improvements to eliminate existing storing and handling problems.
- Providing chemists and operators with physical and chemical data necessary for the most effective use of alum.
- Assisting in laboratory tests and plant trials.
- Running check analyses in our own laboratories.

In water and sewage plants, our specialists provide valuable help and guidance on storage, handling and feeding problems, as well as the important conversion from dry to liquid alum. They can help plant operators establish the best alum dosage. They recommend coagulation aids to improve flocculation in difficult water or waste treatment conditions.

This kind of Technical Service is one of the reasons why General Chemical is a good company to do business with for *your* plant's aluminum sulfate requirements. We will welcome the opportunity to serve you.

Basic to America's Progress

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Inc.

Tank Painting and Repair:
Koppers Co., Inc.
National Tank Maintenance Corp.

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
Rockwell Mfg. Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey-Sparling Meter Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
B-I-F Industries, Inc.—Builders
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants: see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
Eimco Corp., The
General Filter Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Reconditioning and Formation Testing:
Halliburton Co.
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1959 AWWA Directory.

Pure filtered water... YOUR RESPONSIBILITY

Quality controlled alum... OUR RESPONSIBILITY

You can order Cyanamid Alum for your filtration processes with the utmost confidence because Cyanamid Alum is quality controlled from start to finish to meet stringent specifications. Manufacturing plants are strategically located to give efficient service throughout the country.

Supplied in the form you want

LIQUID — for cleaner, easier, more economical operation. In tank wagons and tank cars from 9 convenient shipping points. Conforms fully to AWWA standards.

DRY — conforms fully to AWWA standards in ground, rice, lump or powdered grades. Bagged or bulk.

THINKING OF CONVERTING TO LIQUID? Your costs—and savings—can be determined quickly by a Cyanamid representative with years of conversion experience at your service. Just call Cyanamid for product or technical service.

ALUM CYANAMID

AMERICAN CYANAMID COMPANY

Process Chemicals Department, 30 Rockefeller Plaza, New York 20, N. Y.
In Canada: Cyanamid of Canada Limited, Montreal and Toronto

Why this "magnetic" meter attracts more revenue

Since Rockwell first introduced the Sealed Register meter, the center of attraction has been its magnetic drive. But this magnetic principle does a lot more than attract the eye. It attracts more revenue, especially at low flows. That's because there is no friction from a conventional stuffing box, gear train, driving dog or register to cause a drag on the measuring chamber.

This meter attracts substantial savings in maintenance, too, through having fewer parts—only two of which operate in water.

Another big attraction is the hermetically sealed register which cannot fog or become dirt encrusted—hence is always easy to read.

Now you can get these "magnetic" meters in a complete range of sizes from ⅝" through 2". In any size, for any service, these meters will attract more revenue to you. Write for catalog. Rockwell Manufacturing Co., Pittsburgh 8, Pa. In Canada: Rockwell Manufacturing Co. of Canada, Ltd., Guelph, Ont.

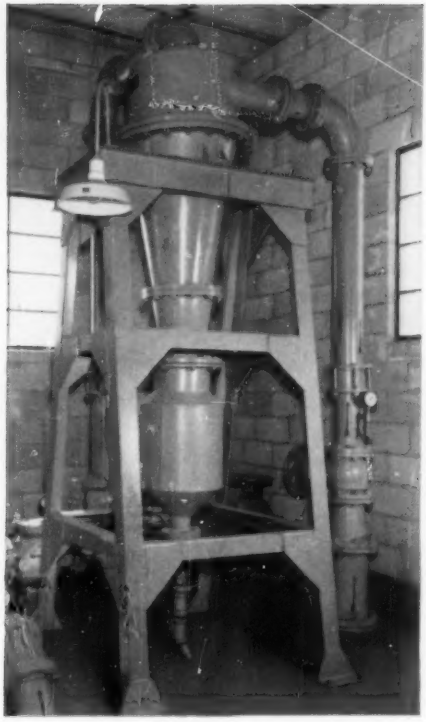
POWERFUL MAGNETIC DRIVE

Illustrating how the driver magnet (held in hand) revolves around a watertight compartment at base of register to push the follower magnet, which in turn drives the register shaft.

SEALED REGISTER METERS

another fine product by

ROCKWELL



DORRCLONE® REMOVES DAMAGING SAND AND SILT

from water system of South Salt Lake City, Utah

This DorrClone installed at South Salt Lake City has a 24" diameter. It is designed to handle 750 gpm at 125 psi and to remove sand and silt at a mesh of separation of 250-300. Units can be designed to remove particles as fine as 500 mesh and to have a maximum flow of 2,000 gpm. Installation is simple. DorrClones have no moving parts—a vortex action, created by pump pressure, removes sand and silt. For more information, write Dorr-Oliver Incorporated, Stamford, Conn.

DORR-OLIVER

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

"Specified and used over 600,000 feet of Transite Water Pipe."

A. R. Todd, Consulting Engineer,
A. R. Todd and Associates,
Wheeling, W. Va.

"Transite® Pipe gives our clients distinct advantage in economy," says Mr. Todd. "It is quick and easy to install, and once in service the economies continue. That's because Transite remains unaffected by external or internal corrosion, assures a tight and flexible installation for the life of the system, protects the quality of the water it carries, and minimizes maintenance and operation costs. We have found these features to be very important in an area known for highly corrosive soils and rocky terrain.

"We have specified and used over 600,000 feet of Transite Water Pipe in the past ten years on dozens of projects. We are convinced that Transite is the best value for the money. Our clients have been well-satisfied, too."

Why not let Transite help *you* reduce community water system costs? Let us send you our "Facts and Data for Engineers" book. Write Johns-Manville, Box 14, JA-12, N. Y. 16, N. Y. In Canada: Port Credit, Ontario. Offices throughout the world. Cable address: Johnmanvil.

JOHNS-MANVILLE JM